SWRHL-72r

FINAL REPORT OF ENVIRONMENTAL SURVEILLANCE FOR PHOEBUS 2A REACTOR TEST SERIES, MAY - JULY 1968

by
Environmental Surveillance
Southwestern Radiological Health Laboratory

U. S. Department of Health, Education and Welfare
Public Health Service
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Environmental Control Administration
Bureau of Radiological Health

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This surveillance performed under a Memorandum of Understanding (No. SF 54 373)
for the
U. S. ATOMIC ENERGY COMMISSION

ABSTRACT

During the months of May through July 1968, the Phoebus 2A nuclear reactor (5000 Mw design-power) was tested through five Experimental Plans (EP's) at Test Cell C, Nuclear Rocket Development Station. For these tests the Southwestern Radiological Health Laboratory conducted radiological monitoring and environmental sampling in off-site areas surrounding the Test Range Complex. During EP III, IV, and V, the reactor was operated at power levels near 2000 Mw, 4000 Mw, and 4000 Mw, respectively, releasing airborne radioactivity which was detected in off-site areas. The EP III effluent traveled southeast from Test Cell C, being detected between Mercury and Las Vegas, Nevada. The effluent from EP IV traveled to the northeast as far as Monticello, Utah, with other portions being detected at Bishop, California, and Lathrop Wells, Nevada. The EP V effluent traveled to the northeast and was detected as far as Wendover, Utah.

As a result of these tests, some radioactive contamination occurred off-site which was detected in air and vegetation samples collected following the three tests and additionally in milk and cow feed samples collected for EP IV and V. Only the EP III and EP V effluents were detectable with GM survey instruments. The maximum external radiation exposure measured off-site following EP V was less than 0.1 mR at Queen City Summit, an unpopulated area. The maximum postulated absorbed dose to the thyroid of a child with a 2-g thyroid was 13 mrad at Blue Eagle Ranch following EP V. These doses were below the radiation protection standards of AEC Manual, Chapter 0524.

PREFACE

In accordance with Memorandum of Understanding, SF 54 373, the Southwestern Radiological Health Laboratory (SWRHL) provides an off-site radiological safety program for the Atomic Energy Commission (AEC) in support of nuclear tests conducted at the Nevada Test Site (NTS) and at the Nuclear Rocket Development Station (NRDS), which lies adjacent to NTS. In this capacity SWRHL is responsible for the following during reactor tests at NRDS:

1. Assuring continuous protection of public health and safety by determining potential and past exposures to radioactivity, and implementing protective measures as directed by the Test Manager, AEC.

2. Documenting the radiological situation in off-site areas through comprehensive environmental sampling and radiation monitoring.

3. Conducting a public contact and information program in the off-site area to assure local residents that all reasonable safeguards are being employed to protect public health and property from radiation hazards.

4. Collecting information regarding incidents which may be attributed to radioactive releases to the off-site area.

Off-site areas are considered those outside the boundaries of NTS, NRDS, the Tonopah Test Range, and the Nellis Air Force Range, which together are referred to in this report as the Test Range Complex.

The SWRHL represents the Bureau of Radiological Health (BRH), within the Department of Health, Education, and Welfare, and thereby maintains close working relationships with other components of BRH and the surrounding states. When any off-site radiological safety operation is conducted, all appropriate parties are kept advised and all state and BRH surveillance networks are alerted, as appropriate, to assist in documenting levels of radioactivity.

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INTRODUCTION

During the months of May through July 1968, the Phoebus 2A nuclear reactor was tested through five Experimental Plans at Test Cell C, Nuclear Rocket Development Station. Only Experimental Plans III, IV, and V of this test series released airborne radioactivity. Radiological monitoring and environmental sampling were conducted by the Southwestern Radiological Health Laboratory (SWRHL) to document the levels of airborne and deposited radioactivity resulting from these tests in off-site areas. This report summarizes the procedures used for the off-site surveillance operations and presents the data obtained except for the monitoring missions of the U-3A and SWRHL aircraft and a special study on reactor-released particles of high specific radioactivity. The results of these efforts are reported separately [1, 2].

The Phoebus 2A nuclear reactor was developed and tested by Los Alamos Scientific Laboratory for Project Rover, which is administered by the Space Nuclear Propulsion Office. The reactor was tested during the dates and at the power levels shown in Table 1 [3, 4, 5, 6, 7] to establish basic reactor design and operating characteristics for the development of a reactor which can be used in a nuclear engine for rocket vehicle application.

Table 1. Phoebus 2A experimental plans - 1968

EP	Date	Operating Time (PDT)*	Max. Power Attained (Mw)	Integrated Power (Mw-sec)
I	May 22	0931-1101	< 0.1	31.5
	May 23	0904-1222	< 0.1	70.8
II	May 29	0925-1259	2.3	1.33×10^3
III	June 8	1114-1125*	~2000	6.43×10^5
IV	June 26	1237-1309*	~4000	4.5×10^6
VA	July 18	1310-1322*	< 2200	6.6×10^5
VB	July 18	1450-1508*	~4000	2.0×10^6

*Operating times represent only the portions of the experimental plans during which airborne radioactivity was released.

Airborne radioactivity was released during EP III, IV, and V by high reactor core temperatures and corrosion of the nuclear fuel. With the reactor nozzle positioned upward, the major portion of the effluent was carried several thousands of feet above the ground.

PROCEDURES

Prior to a reactor test at the NRDS, mobile monitoring personnel (monitors) are positioned at populated locations and on highways crossing the predicted effluent trajectory to measure radiation levels and collect environmental samples should airborne radioactivity be released. These monitors are equipped with radiation survey instruments, gamma-rate recorders, thermoluminescent dosimeters, portable air samplers, and supplies for collecting environmental samples. All personnel are in two-way radio contact with a control center which directs their activities.

Following a release of radioactivity, pertinent characteristics of the effluent are determined by aerial monitoring. A U. S. Air Force U-3A aircraft defines the boundaries and hotline of the radioactive cloud, and a SWRHL Turbo-Beech is used to perform cloud sampling, monitoring, and other documentative missions, as required. All tracking data are radioed immediately to the control center. This information, in conjunction with meteorological and on-site monitoring information, is used in directing the final placement of portable air samplers, portable recorders, TLD's and ground monitors.

While the effluent passes off-site, air samples and survey meter readings are taken. Following the passage of the effluent, levels of environmental radioactivity are documented by comprehensive sampling and monitoring. Monitors take radiation readings in the affected areas and collect vegetation, milk, cow feed, and water samples. Highways located in the effluent trajectory are also monitored by a vehicle-mounted mobile scanner of high sensitivity for gamma radiation to measure the boundaries of any radioactive deposition on the ground.

Further details on equipment, procedures, and analysis techniques are given in Appendix A.

For those tests where the reactors are operated near full-power, a study is conducted to locate, collect and analyze particles of high specific radioactivity which are deposited on the ground downwind of the tests. The results of this study, as mentioned previously, are reported separately [2].

EP III RESULTS

Radiation measurements from the U-3A and Turbo-Beech aircraft indicated that the effluent produced by Experimental Plan III drifted off-site in a general heading of between 120° and 135°. Based upon this information, monitors were deployed to locations on Highway 95 (Figure 1) near populated areas within the anticipated effluent trajectory, and a gamma-rate recorder was operated at SWRHL in Las Vegas until the following morning. The effluent was barely detectable off-site by Geiger-Mueller survey instruments. Those readings which were above background are presented in Table 2.

Table 2. Summary of GM survey instrument readings
Phoebus 2A EP III, June 8, 1968

Location Description	Azimuth & Distance from Test Cell C (degrees)	(mi)	Cloud Arrival Time	Max. Gamma Above Background mR/hr	Time
Highway 95, 8 mi W. of Cactus Springs, Nev.	128	28	1305	0.02	1312
Cactus Springs, Nev.	120	35	1310	0.05	1313
Indian Springs, Nev.	117	38	1320	0.02	1328

Monitors collected precipitation samples during cloud passage and samples of natural vegetation after cloud passage at the locations shown in Figure 2. The result of each sample is indicated as being positive or negative for reactor-related radioactivity. The radionuclides in the positive samples were identified as ^{133}I, ^{135}I, and ^{91}Sr.

Air samplers from the routinely operated Air Surveillance Network were running at Lathrop Wells, Indian Springs, and Las Vegas, Nevada. In addition portable air samplers were set up at Cactus

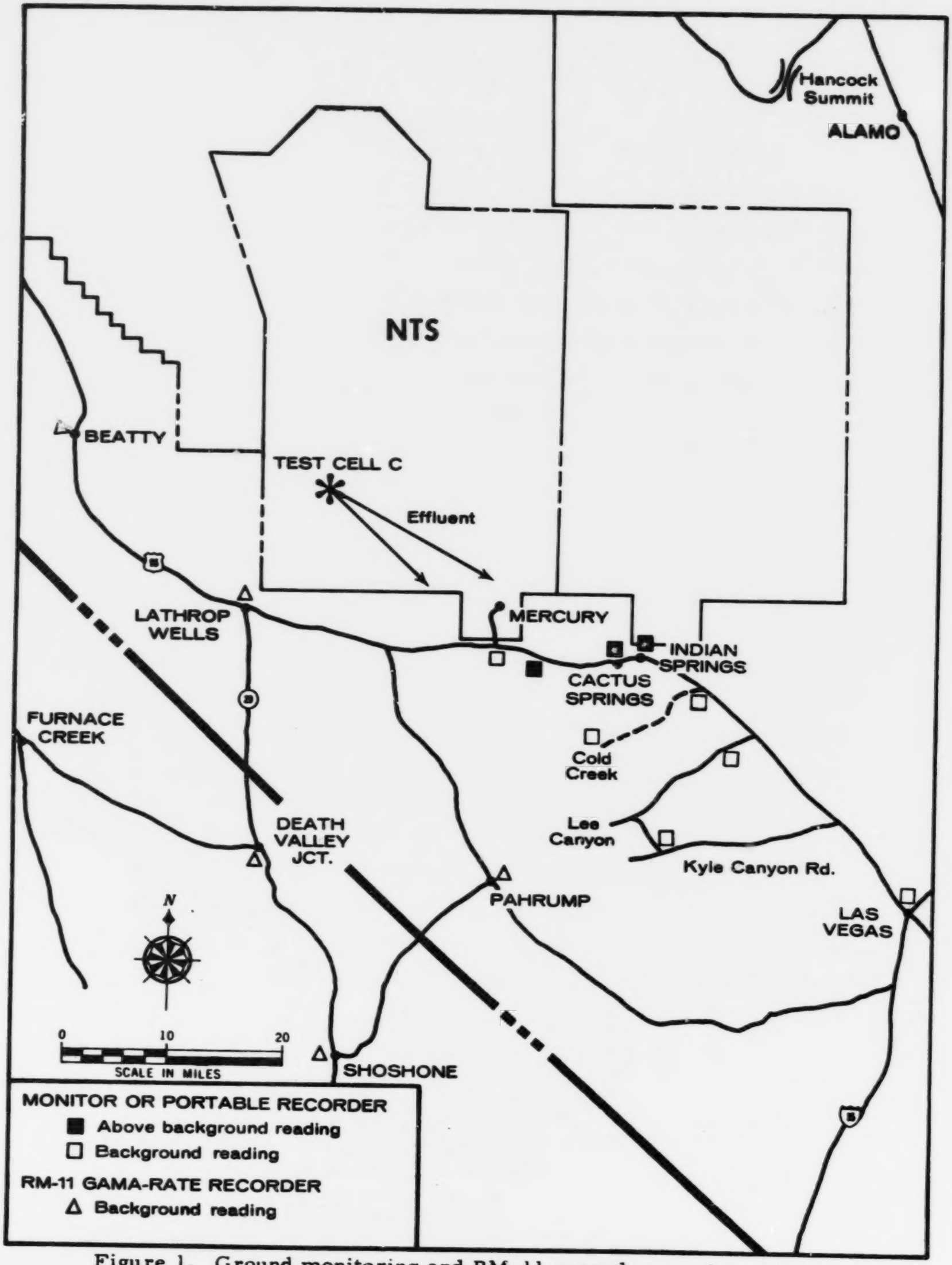

Figure 1. Ground monitoring and RM-11 recorder results - EP III

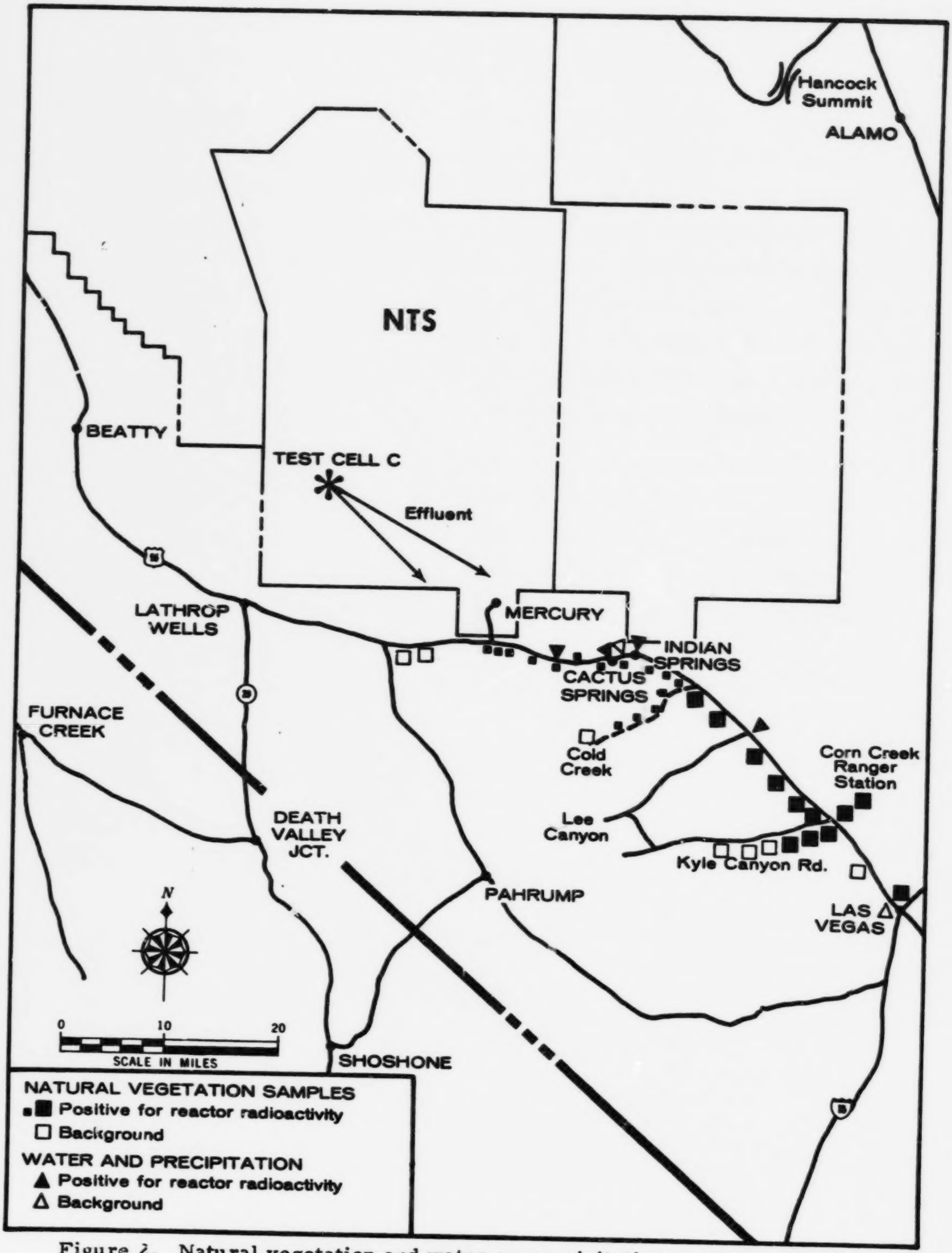

Figure 2. Natural vegetation and water or precipitation results - EP III

Springs and at the Mercury turn-off on Highway 95. As shown in Figure 3, the Phoebus 2A EP III effluent was detected off-site only by the air samplers at Indian Springs and Cactus Springs. The concentration of gross beta radioactivity and the concentrations of specific radionuclides indentified by gamma spectrometry are shown in Table 3. The concentrations of radioiodine at Indian Springs, if inhaled, were equivalent to an estimated radiation dose (Appendix B) of less than 1 mrad to the thyroid of an adult or less than 3 mrad to the thyroid of a one-year-old child.

Following the reactor test, no radioactivity was detected in milk and cow feed samples collected within the effluent trajectory. On the evening of the test a pasture sample was collected at the LDS Dairy Farm (a Grade A milk producer), Las Vegas. Two days after the test, milk, cow feed and stock-tank water samples were collected at the Jim Fisher Ranch, Indian Springs. No reactor-related radioactivity was detected in any of these samples.

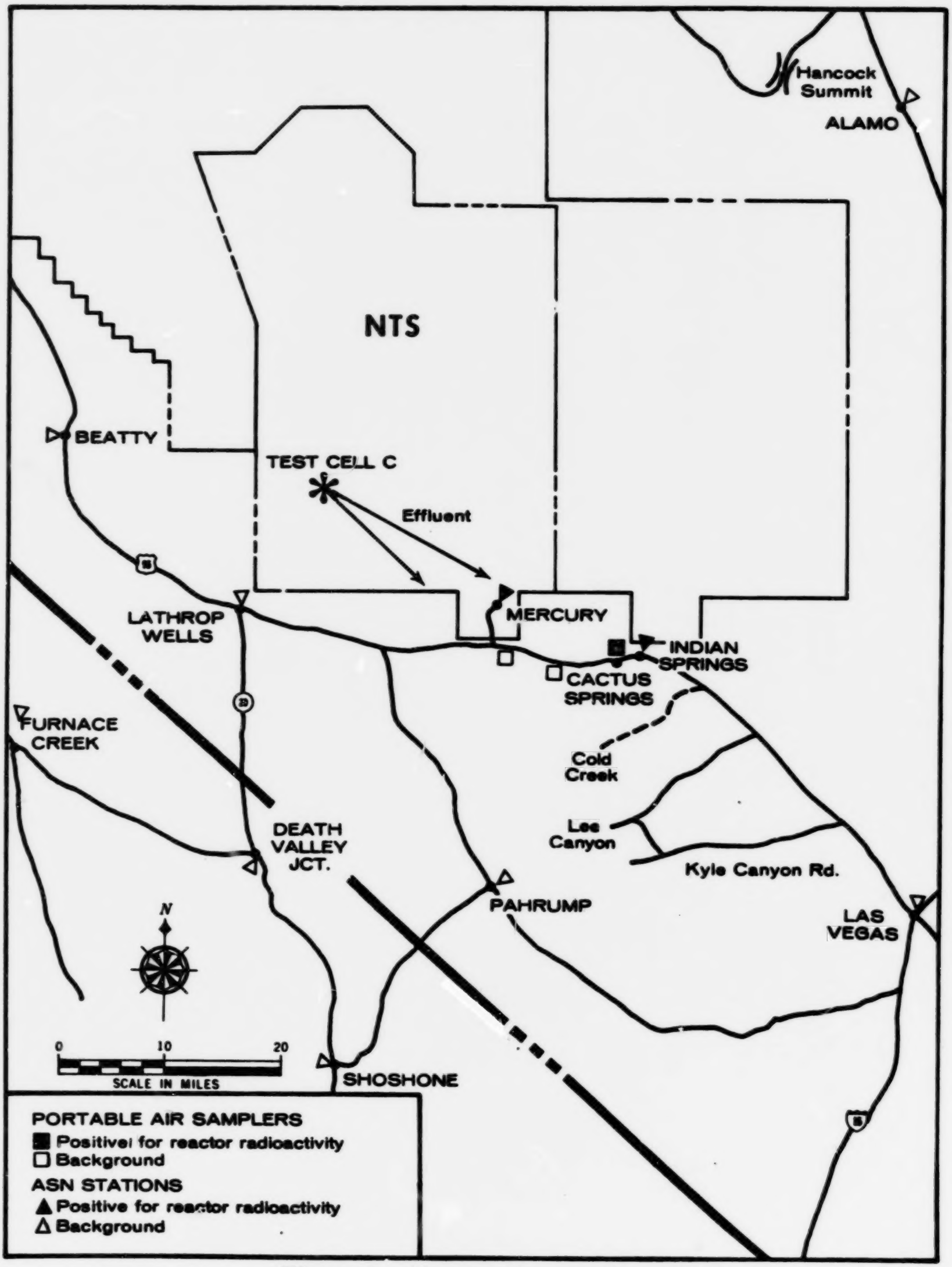

Figure 3. Air sampling results - EP III

Table 3. Off-site airborne radioactivity concentrations following Phoebus 2A EP III

Location	Collection Period Date & Time On / Off	Type*	Concentrations Extrapolated to End Collection Gross B pCi/m³	Gross B μCi·sec/m³	^{133}I pCi/m³	^{133}I μCi·sec/m³	^{135}I pCi/m³	^{135}I μCi·sec/m³
Indian Springs, Nevada (117°, 38 mi)	6/8-0900 / 6/8-1500	PF	150	3.3	2.8	0.06	4.7	0.10
		CC	--	--	ND	ND	ND	ND
Cactus Springs, Nevada (120°, 35 mi).	6/8-1220 / 6/8-1345	PF			Filter Lost			
		CC	--	--	0.2	0.01	10	0.50

*CC - charcoal cartridge
*PF - particulate filter
ND - not detected

EP IV RESULTS

Experimental Plan IV was conducted on June 26, 1968, with the effluent release occurring over a period from 1237 to 1309 hours. At 1316 hours and 8000 feet above Mean Sea Level (MSL) the major portion of the EP IV effluent was located by the U-3A aircraft along azimuths of 50-55°, about six miles from Test Cell C, elevation 3800 feet. SWRHL aircraft also detected a portion of the release at 18,000 feet and the trajectory for this altitude curved south into California and turned back into Nevada north of Tonopah [1]. Mobile monitors were deployed to Highways 93 and 25 where portable gamma exposure-rate recorders with two TLD's each were left overnight at the locations shown in Figure 4 to supplement the permanent SWRHL networks of TLD's and gamma-rate recorders. Highway 25 between the Valley Road turn-off and the junction with Highway 93 was also monitored with the mobile scanner shortly after 2000 hours. No radiation levels above background were detected by the scanner, the radiation recorders which functioned properly, the TLD's or monitors who were in the area until 2200 hours.

On the following day, Highway 93 from Panaca to Junction 93/15 and Highway 15 from Junction 93/15 to 15 miles east of Mesquite were surveyed by the mobile scanner (Figure 4). No radiation levels above background were detected.

In addition to the routine dosimetry network and the TLD's within the previously mentioned recorders, TLD's were placed south of Test Cell C at one-mile intervals along Highway 95 between Beatty and the Mercury turn-off. These TLD's were positioned on the day

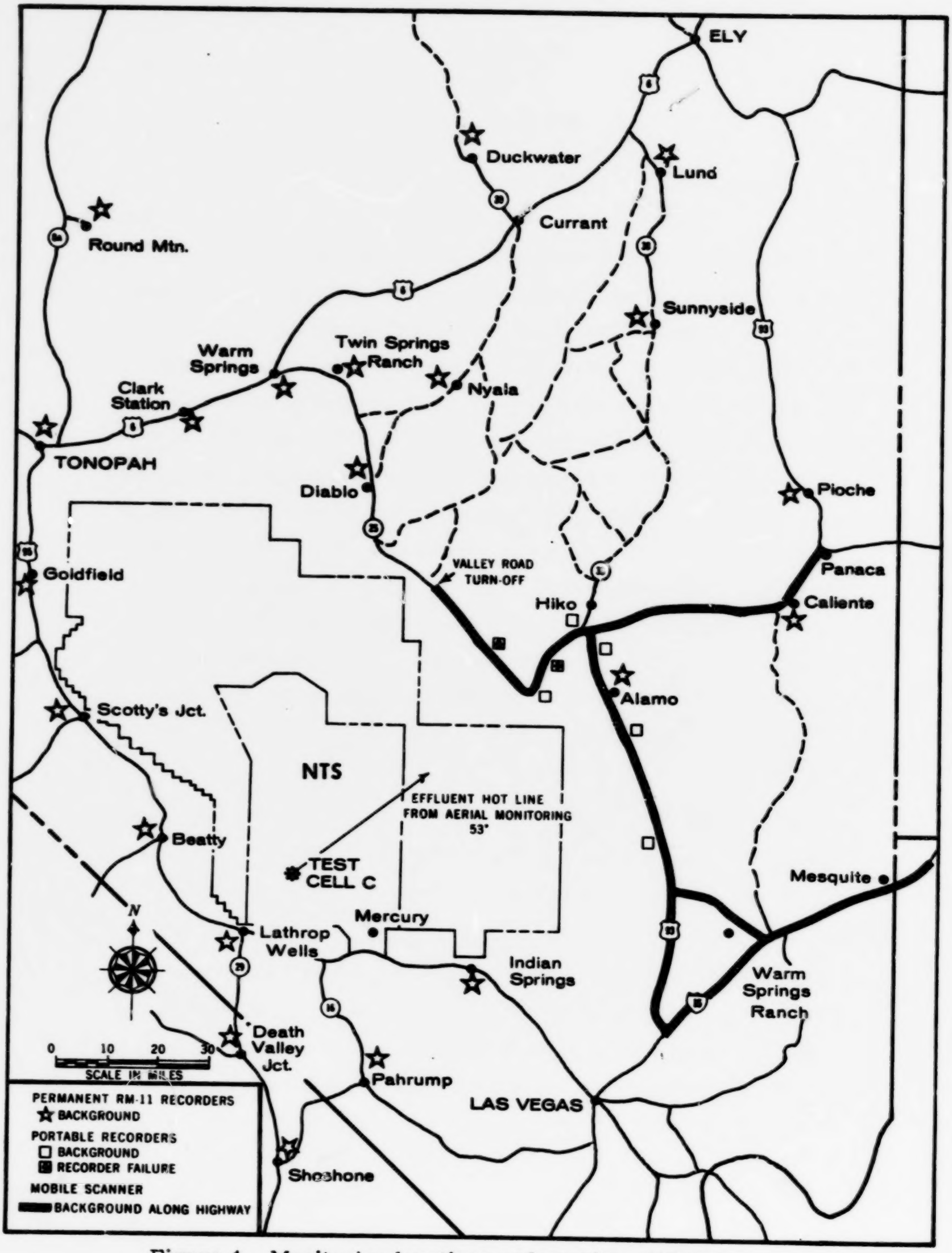

Figure 4. Monitoring locations and results - EP IV

of the test and retrieved at the end of pulse-cool-down (removal of decay-heat with periodic pulses of nitrogen gas), 144 hours after reactor shutdown. No radiation above normal background was detected on these dosimeters.

Samples of natural vegetation were collected off-site downwind of Test Cell C at the locations shown in Figure 5. Those samples on which radioactivity was deposited were located between azimuths of 18° and 62°. The levels of radioactivity on the samples were low showing no apparent hot-line.

The routine Air Surveillance Network was supplemented with 14 portable air samplers which were placed within the anticipated off-site trajectory at populated areas and along an arc 100 miles from Test Cell C. These samplers ran overnight. Quantitative data were obtained from five of these and five others showed evidence of the reactor effluent. Figure 6 shows the locations of those air samplers which collected reactor-related radioactivity.

As shown by Figure 6, radioactivity was collected by air samplers to the east and northeast into southern Utah, at Bishop, California, and at Indian Springs, Nevada. The movement of the effluent to the east and northeast agrees with meteorological information [8] which indicated that the trajectories of effluent parcels released between 8000 feet and 12,000 feet MSL would go to the east and northeast. The effluent trajectory found at 18,000 feet by SWRHL aircraft [1] might explain the positive sample at Bishop, California, collected between 1700 hours on June 27 and 28. The positive sample at Indian Springs collected between 0900 hours on June 26 and 27 was most likely a result of radioactivity which moved to the northeast at a low altitude and was affected by drainage winds from the north.

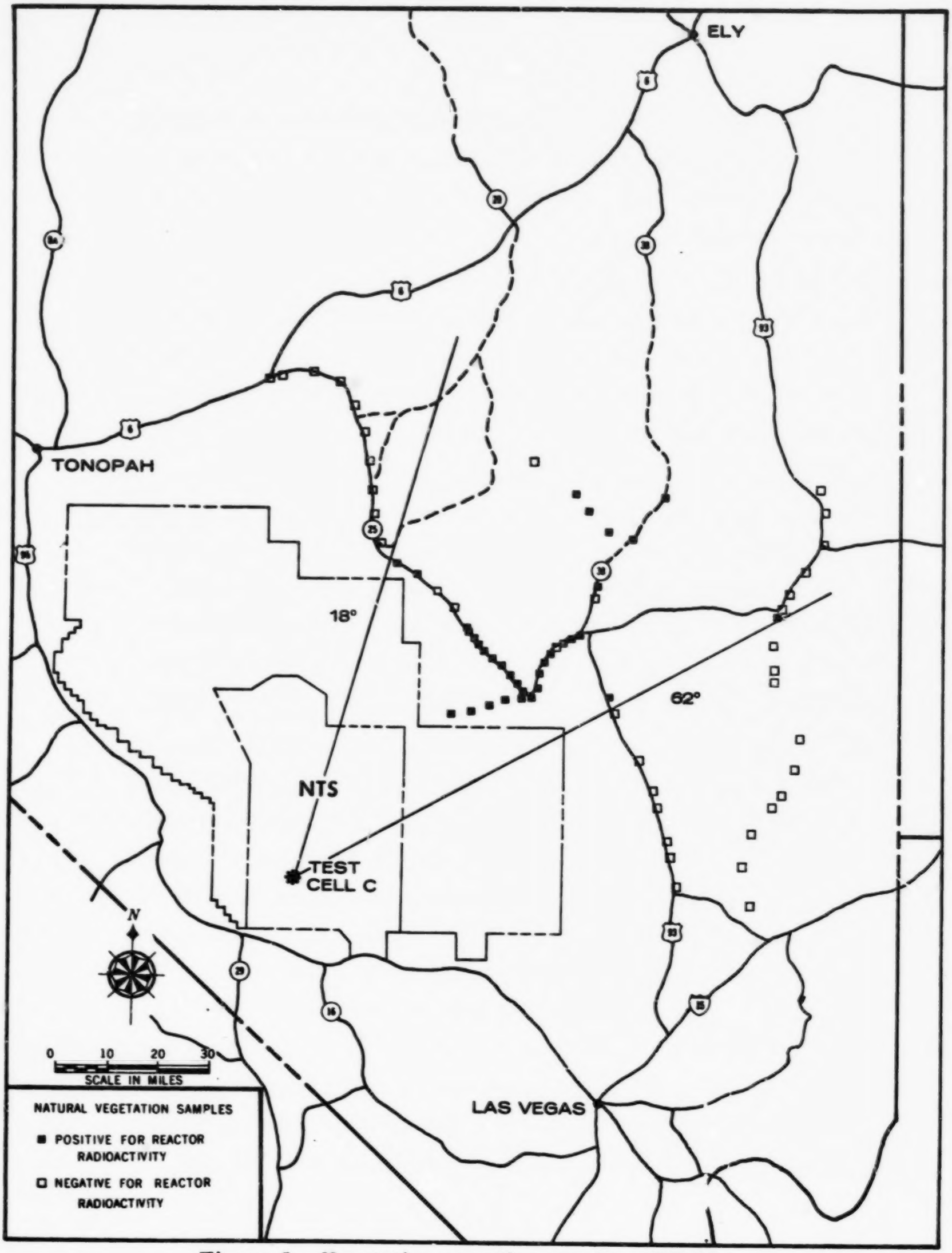

Figure 5. Vegetation sampling results - EP IV

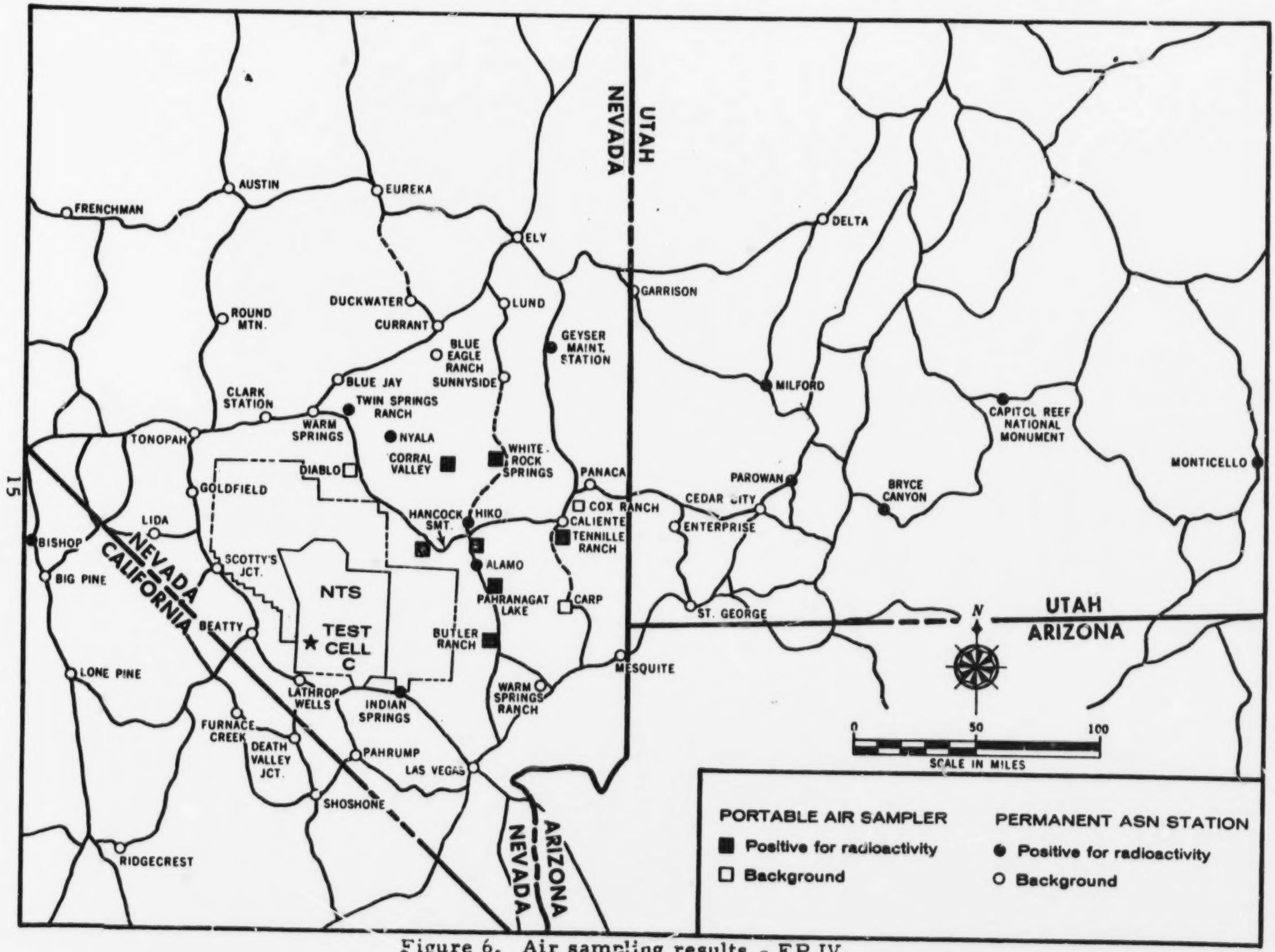

Figure 6. Air sampling results - EP IV

Appendix C.1 presents the air sampling results for those sampling locations which collected radioactivity from EP IV. The highest levels of airborne radioactivity occurred at an unpopulated location on Highway 25, 11.5 miles west of Hancock Summit. The time-integrated exposure levels at this location were 1.6 $\mu Ci \cdot sec/m^3$ for ^{131}I, 4.4 $\mu Ci \cdot sec/m^3$ for ^{132}Te, and 8.7 $\mu Ci \cdot sec/m^3$ for ^{133}I. The adult thyroid dose calculated from these levels by the method of Appendix A was 1.6 mrad. At Hiko, the adult thyroid dose from radioiodine inhalation was estimated to be 0.2 mrad. For postulated doses to a one-year-old child at these locations the adult doses must be multiplied by a factor of 3 to compensate for differences in thyroid size and in breathing rate.

To detect the presence of the EP IV effluent in view of the uncertainty in its trajectory, milk and cow feed samples were collected around the Test Range Complex within five days after the test at ranches which are normally sampled monthly. All of these sampling locations are shown in Figure 7 with each location identified as having milk and/or feed samples positive or negative for radioactivity. All milk and cow feed sampling results are listed in Appendix C.2 for those locations at which radioactivity was detected either in the feed or the milk. Concentrations of 30 pCi/l of ^{131}I were found at Schofield's Dairy, Hiko, Nevada, over a nine-day period after which sampling was terminated. Based upon conservative assumptions, the maximum estimated dose to a child's thyroid would be 9.5 mrad. This combined with an estimated child inhalation dose of 0.6 mrad at the same location gives a total dose of 10 mrad at the closest location within the effluent trajectory where exposure could occur from inhalation and ingestion.

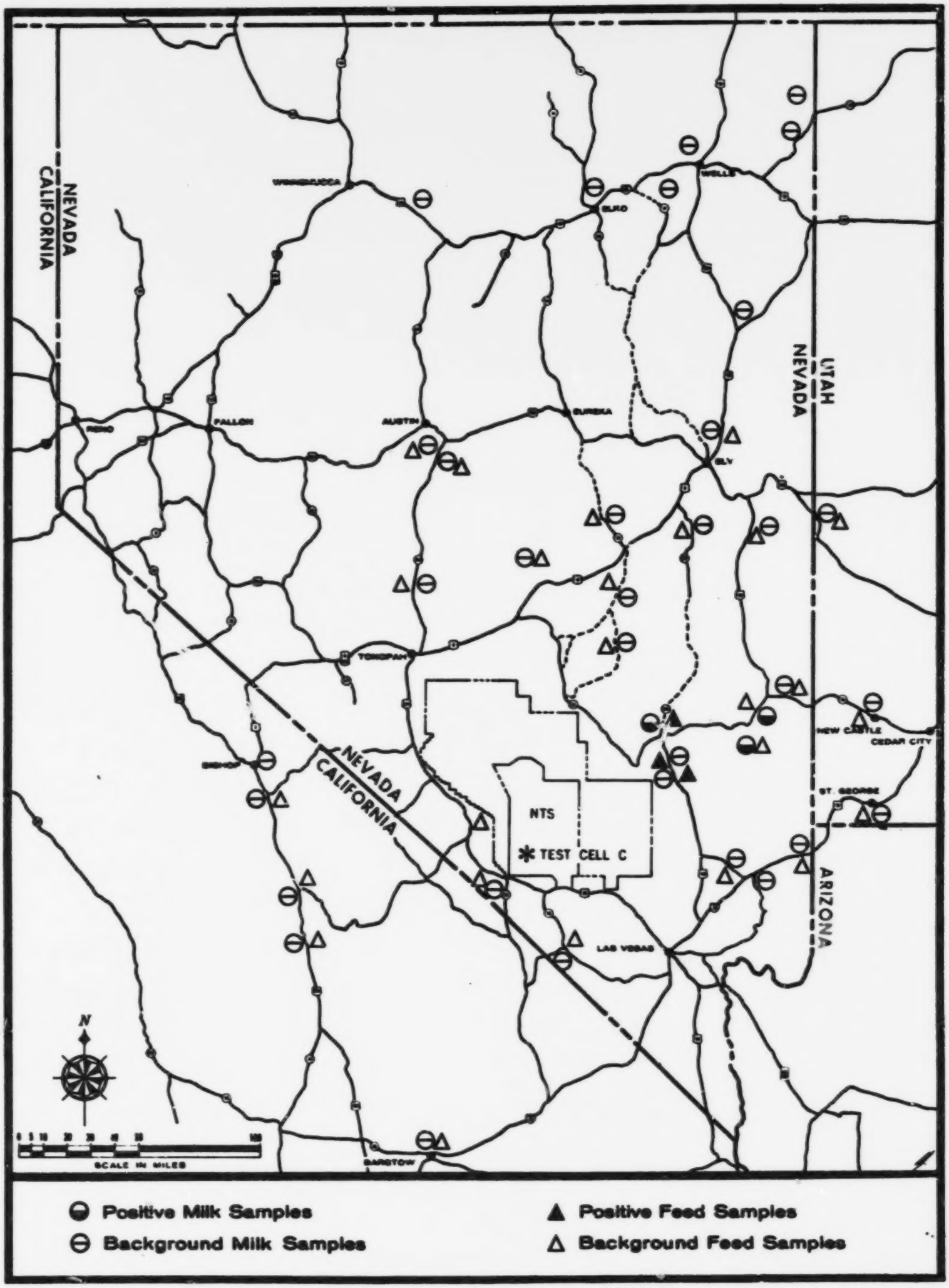

Figure 7. Milk and feed results - EP IV

Seventy-six water sampling locations, shown in Figure 8, which are normally sampled monthly were sampled within a few days after EP IV. No radioactivity associated with EP IV was detected in any of these samples.

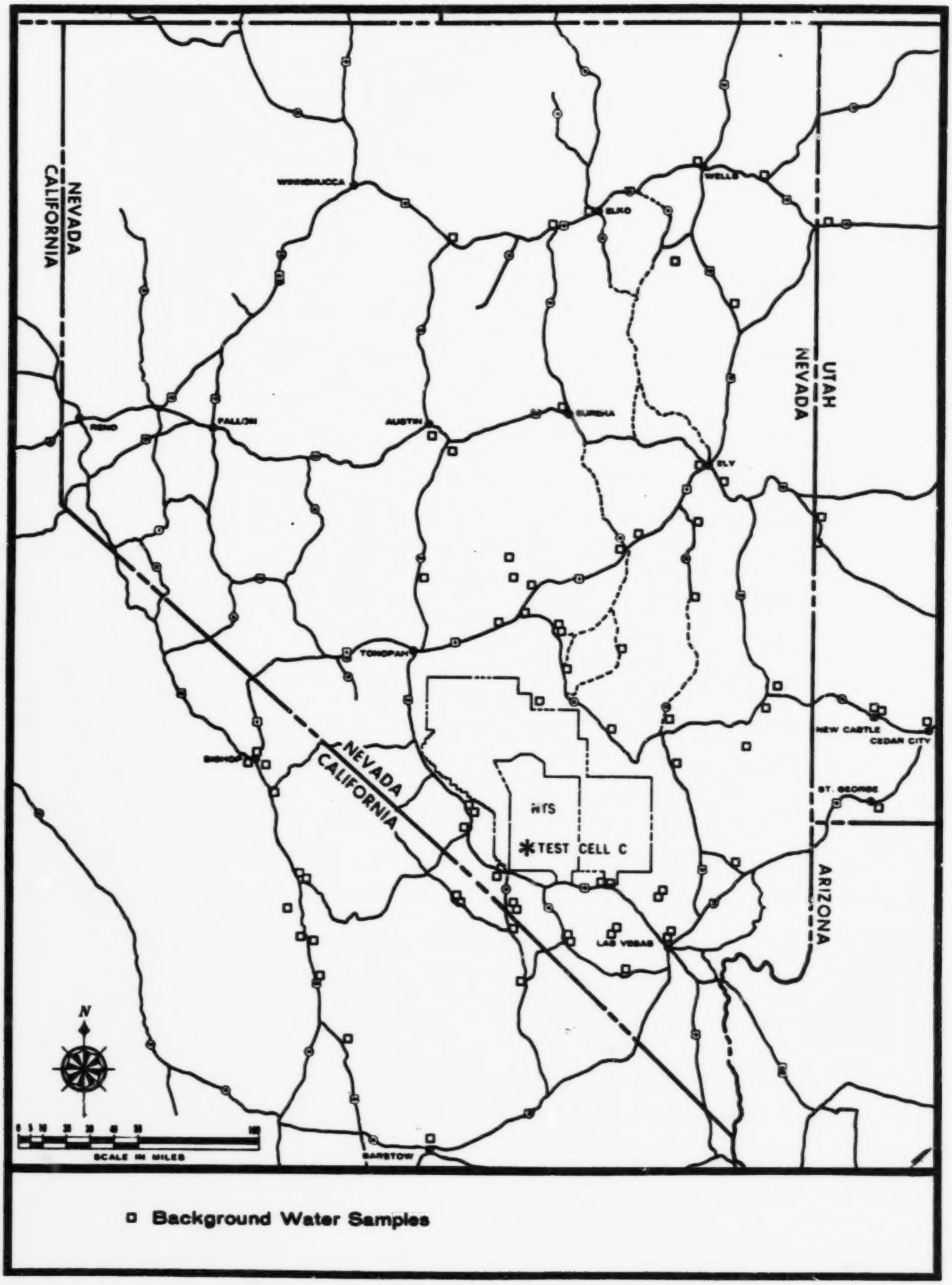

Figure 8. Water sampling results - EP IV

EP V RESULTS

Based on early trajectory information obtained from the U-3A and PHS aircraft, off-site monitors were positioned on Highway 25 northeast of Test Cell C to monitor the effluent released by EP V. Radiation readings were taken by monitors and gamma-rate recorders at the locations shown in Figure 9. The EP V effluent was detected off-site at Queen City Summit (16°, 66 mi from Test Cell C) upon arrival of a monitor at 2007 hours which was shortly after cloud arrival. From the average effluent speed of 13 mph estimated by aircraft (1) and the reactor start-up time of 1950 hours, cloud arrival time was estimated to be 2000 hours at this location. The maximum gamma-rate reading at this location was 0.08 mR/hr above background. Radiation readings were at background levels several miles either side of the summit. The maximum gamma exposure at Queen City Summit, an unpopulated area, was estimated to be less than 0.1 mR. Recorders operating overnight at other locations shown in Figure 9 did not indicate readings above background.

In addition to the routine dosimetry network, TLD's were placed at three-mile intervals on Highway 6 and 25 from Alamo to Tonopah to detect cloud passage and along Highway 95 from Beatty to the Mercury turn-off at one-mile intervals to monitor releases during reactor pulse-cooling operations. No significant exposures above normal background levels were detected.

Personnel using the mobile scanner monitored Highway 50 between Eureka, Nevada, and the Utah border (19 July), Highway 6 between Ely and Warm Springs (20 July), and Highways 25 and 93 between Warm Springs and Las Vegas (20 July). No radioactivity was detected above

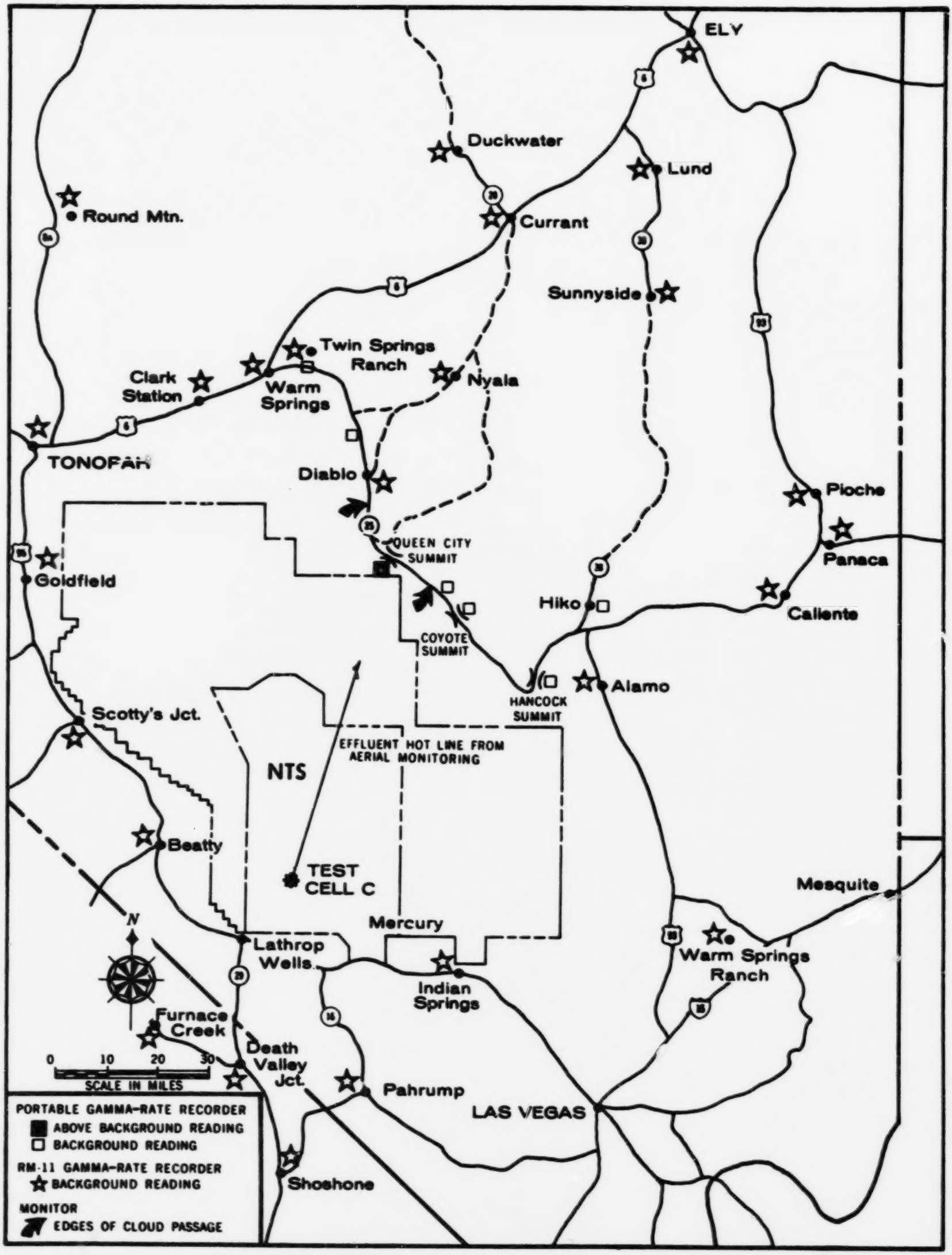

Figure 9. Ground monitoring results - EP V

normal background, which had been determined for the surveyed areas prior to the reactor test.

The locations of natural vegetation samples collected to define the deposition pattern of the EP V effluent are shown in Figure 11 with each sampling location indicated as positive or negative for reactor-related radioactivity. As shown by Figure 11, the eastern edge of the deposition pattern was at an azimuth of 47° and the western edge was west of 350°. Based upon the gamma cpm/kg for the samples collected along Highway 25 and 6 (Figure 10), the area of highest concentration was two miles west of Queen City Summit (66 miles on an azimuth of 16° from Test Cell C).

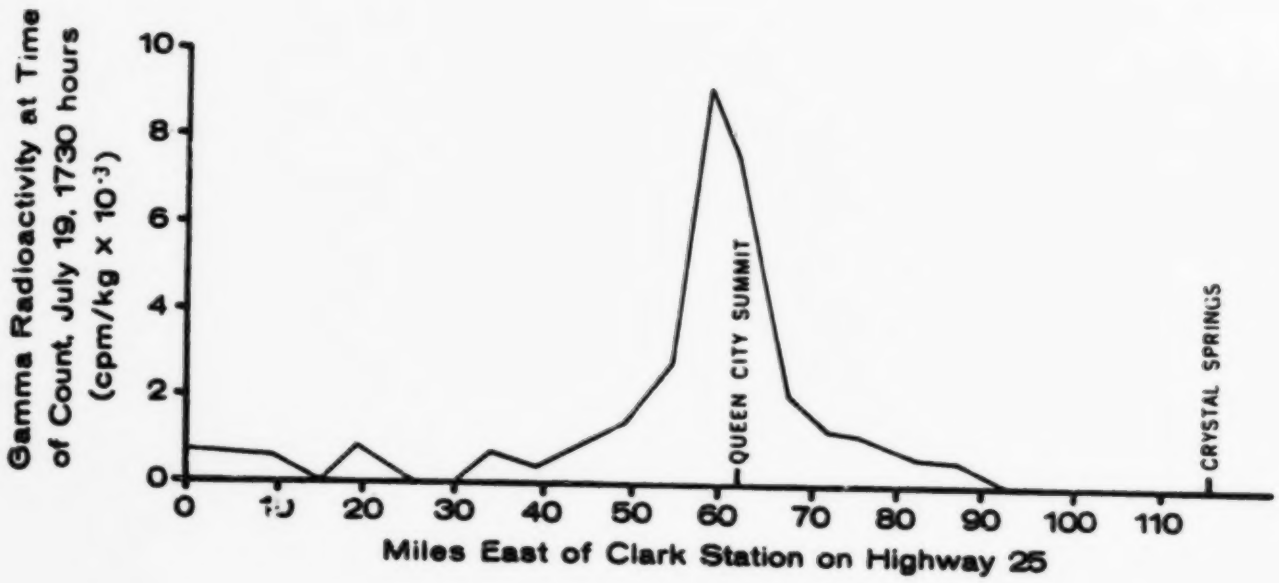

Figure 10. Relative concentration of radioactive deposition on natural vegetation

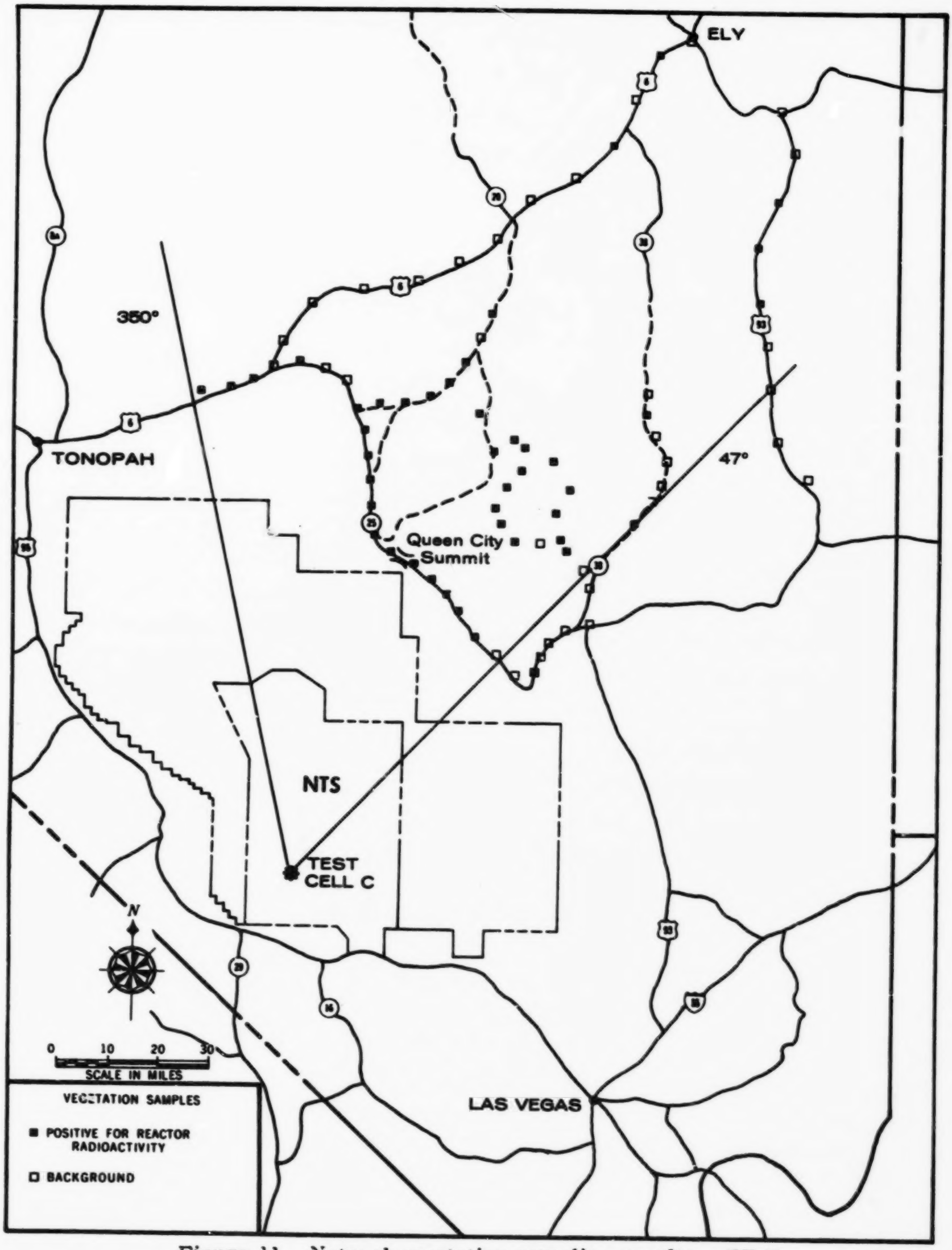

Figure 11. Natural vegetation sampling results - EP V

Seven portable air samplers were positioned off-site to supplement the routine PHS Air Surveillance Network (ASN). Four of the portable samplers were placed at 5° intervals on an arc approximately 100 miles from Test Cell C, two were placed on Highway 25 and one was located at the Kirkeby Ranch near Shoshone, Nevada. Figure 12 shows the ASN stations and the portable air sampler locations at which samples were positive for the EP V effluent. All stations yielding positive samples were within azimuths of 10° and 39° from Test Cell C except for Lathrop Wells. The radioactivity detected at this station was most likely from northerly drainage winds carrying portions of the effluent releases from reactor-pulse-cooling operations, which continued until 48 hours after the test.

Appendix D.1 lists the locations of those sampling stations where positive samples were collected and lists the concentrations of gross beta radioactivity and the concentrations of radioisotopes identified by gamma spectrometry. As indicated by Appendix D.1, combinations of ^{131}I, ^{132}Te, ^{133}I, and ^{135}I were identified in the samples. Of the locations sampled, the maximum exposure to airborne radioactivity in the immediate off-site area was at Queen City Summit, an unpopulated area (16° and 66 miles from Test Cell C). The radiation dose to an adult's thyroid was estimated from the radioiodine concentrations at this location to be 2.6 mrad by the method described in Appendix B. At 100 miles from Test Cell C, the maximum exposure to airborne radioactivity was at a 25° azimuth. The maximum possible dose to an adult's thyroid at this position was estimated to be 2.1 mrad. Neither of these locations was populated. The populated areas closest to these locations are the Sharp Ranch (17°, 102 miles) at Nyala and two ranches (Gunderson Ranch and Nevada Farms) within Penoyer Valley, about 12 miles southeast of Queen City Summit.

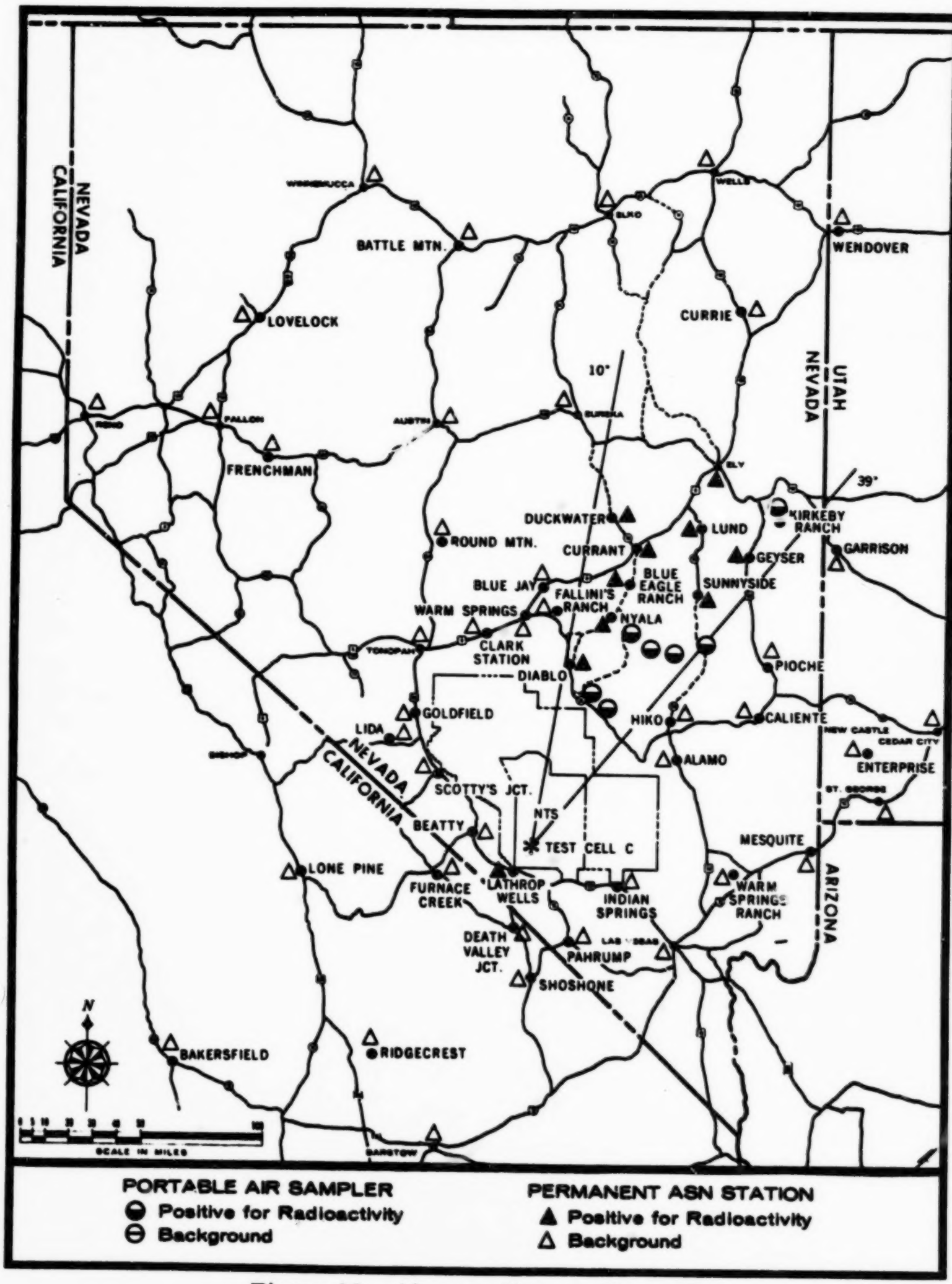

Figure 12. Air sampling results - EP V

Milk and feed samples were collected from the 16 locations shown in Figure 13. Those locations identified in the figure as having samples containing reactor-related radioactivity are listed in Appendix D.2 with analysis results. Only at four locations was radioiodine detected in the milk samples. Table 4 below lists the postulated radiation dose to the thyroid of a one-year-old child from a 1 liter/day milk consumption at these four locations. Air samplers were operated at three of the four positive milk sampling locations. The postulated child thyroid doses from inhalation are also included in Table 4.

Table 4. Postulated thyroid dose to one-year-old child from milk consumption and from inhalation

Name	Location		Thyroid Dose, mrad		
	Azimuth (°)	Distance (mi)	From Inhalation	From Milk	Total
Blue Eagle Ranch Currant, Nevada	18	125	3	10	13
Halstead Ranch Duckwater, Nevada	13	143	< 1	8	8
Sharp Ranch Nyala, Nevada	16	102	2	8	10
Paris & Sons Ranch Cherry Creek, Nevada	17	238	--	5	--

Water samples were collected at all but one of the ranches where milk and feed samples were obtained. No radioactivity was detected in any of the water samples.

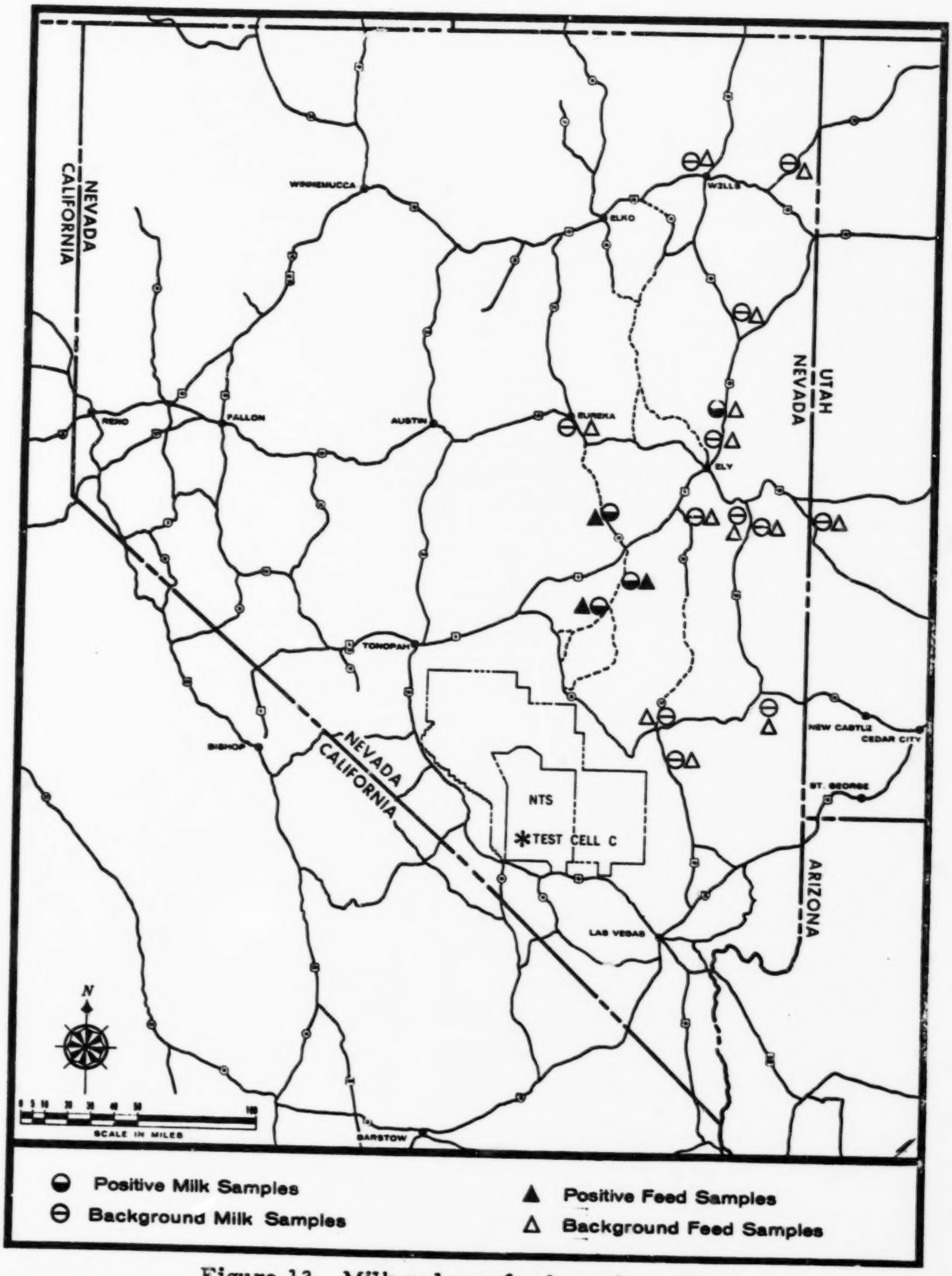

Figure 13. Milk and cow feed results - EP V

SUMMARY

The radioactive effluents resulting from EP III, IV, and V were detected outside the Test Range Complex by radiation monitoring and/or environmental sampling. The radiation exposures and hypothetical doses estimated from these measurements were below the radiation protection standards of AEC Manual, Chapter 0524. These standards are as follows:

Type of Exposure	Annual Dose in Rem	
	Based on Dose to Critical Individuals at Point of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population
Whole body, gonads or bone marrow	0.5	0.17
Other organs such as thyroid	1.5	0.5

EP III

The radioactive effluent of EP III was detected southeast of Test Cell C along Highway 95 toward Las Vegas. Geiger-Mueller survey instrument readings by monitors along the highway were low with a maximum reading of 0.05 mR/hr gamma above background observed at Cactus Springs, the closest populated area off-site. No reading above background was detected in Las Vegas.

The majority of natural vegetation samples collected from the NRDS turn-off on Highway 95 to a few miles outside of Las Vegas were positive for radioactivity, but no radioactivity was found on a pasture sample at a Grade A milk producer outside of Las Vegas. The positive vegetation samples contained various combinations of ^{131}I, ^{133}I, ^{135}I, and ^{91}Sr as did samples of precipitation taken at the time of cloud passage.

The samples taken at Cactus Springs and Indian Springs were the only air samples on which effluent was identified. The time-integrated concentration of airborne radioactivity at Indian Springs was 0.06 $\mu Ci \cdot sec/m^3$ for ^{133}I and 0.10 $\mu Ci \cdot sec/m^3$ for ^{135}I. The radiation dose to the thyroid of an adult from these concentrations was estimated to be less than 1 mrad. The charcoal cartridge on the air sampler at Cactus Springs collected radioiodine; however, the particulate filter was lost.

Milk, water and cow feed samples were collected at the Fisher Ranch, Indian Springs, two days after the test, but no reactor-related radioactivity was detected in any of the samples.

EP IV

The major portion of the EP IV effluent traveled northeast of Test Cell C being detected by air samplers as far as Monticello, Utah. Radioactivity releases from this run were detected by air samplers at Bishop, California, and Lathrop Wells, Nevada, as well as the stations to the northeast. The maximum exposure to airborne radioactivity, primarily radioiodine, as calculated from all sample results, was at an unpopulated location along Highway 25, 11.5 miles west of Hancock Summit, at an azimuth and distance of 42° and 72 miles from Test Cell C. The postulated dose to the thyroid of an adult from inhalation at this location would have been 1.6 mrad. At Hiko (48°, 78 miles), the closest populated area with milk cows, the estimated adult-thyroid dose from inhalation was estimated from air sampling results to be 0.2 mrad. The dose to the thyroid of a one-year-old child at those same locations would be a factor of three times the dose for an adult.

The effluent was not detected with GM survey instruments, TLD's or the mobile scanner in the immediate off-site area. However, some radioactive deposition was found on natural vegetation samples collected between 18° and 62° from Test Cell C along roads and highways in the immediate off-site areas.

Due to the large amount of wind sheer which existed at several elevations after the test, milk, cow feed, and water samples were collected at locations surrounding the Test Range Complex. Radioactivity was found only in milk and/or cow feed samples collected near Hiko, Alamo, Caliente, and Panaca. The maximum level of ^{131}I in the milk samples was at Schofield's Dairy, Hiko, where concentrations of ^{131}I were 30 pCi/l over a nine-day period after which sampling was terminated. The maximum dose to the thyroid of a one-year-old child drinking one liter per day of the milk was estimated to be 9.5 mrad. The total estimated dose to a 2 g thyroid of a child from both inhalation and ingestion at Hiko would be 0.6 mrad plus 9.5 mrad or 10 mrad.

EP V

The EP V effluent traveled to the northeast being detected by air sampling stations between azimuths of 10° and 39° from Test Cell C as far out as Wendover, Utah. An air sampler at Lathrop Wells also collected reactor-related radioactivity which was probably from pulse-cool-down operations after the test. Of all air sampling locations the maximum exposure to airborne radioactivity was at Queen City Summit (16°, 66 miles from Test Cell C) an unpopulated location along Highway 25. At 100 miles from Test Cell C, the maximum potential inhalation exposure was in an unpopulated location at a 25° azimuth from Test Cell C. The postulated adult-thyroid

doses from inhalation at these locations were 2.5 mrad and 2.1 mrad, respectively.

Along Highway 25 the effluent was barely detectable with GM survey instruments, the maximum gamma-rate reading and estimated gamma exposure being 0.08 mR/hr above background and less than 0.1 mR, respectively, at Queen City Summit, an unpopulated area. Thermoluminescent dosimeters placed at three-mile intervals along Highway 25 and at one-mile intervals between Beatty and the Mercury turn-off on Highway 95 did not detect any radiation above normal background.

The majority of vegetation samples collected along off-site highways and roads as far as Ely, Nevada, were positive for reactor-related radioactivity between azimuths of 350° and 45° from Test Cell C. The sample having the highest concentration of radioactivity as determined from gamma cpm/kg was collected two miles west of Queen City Summit.

Cow feed and milk samples were collected at 16 ranches within the effluent trajectory. Radioactivity from EP V was detected in the milk and/or the cow feed samples collected at four of these ranches. From the radioiodine concentrations found in the milk the highest postulated dose to the thyroid of a one-year-old child was estimated to be 10 mrad at the Blue Eagle Ranch near Currant, Nevada. From analysis of an air sample collected at this ranch, the postulated dose to the thyroid of a child was estimated to be 3 mrad, giving a maximum postulated dose of 13 mrad.

Water samples were collected at all but one of the milk sampling locations. None contained any radioactivity related to the reactor test.

APPENDIX A

EQUIPMENT AND TECHNIQUES OF SAMPLING AND ANALYSIS

Survey Instruments

The aircraft and ground monitors are equipped with Geiger-Mueller, gamma scintillation, and ionization chamber survey instruments. The Geiger-Mueller (GM) instrument has a range of 0-200 mR/hr on four-linear scales with a range of 0-2000 mR/hr provided by an internal GM detector. The gamma scintillation instrument, used for low-level measurements, has a range of 0-3 mR/hr on three-linear scales. The ionization chamber survey instrument is used for high radiation levels. It has a range of 0.05 to 50,000 mR/hr on two logarithmic scales. These instruments are calibrated with a ^{137}Cs source and are generally accurate to $\pm$ 20%. Exposure-rate readings are precise to two significant digits.

Mobile Ground Scanner

The mobile ground scanner consists of a 4- by 4-inch NaI(Tl) crystal connected to a battery-powered scaler. The scanner is placed within a motor vehicle and operated by taking one-minute counts at preselected intervals while the vehicle moves at a fixed speed along highways crossing the effluent trajectory. These data are then compared with background levels determined prior to tests to identify any deposition pattern.

Gamma-Rate Recorders

A network of 27 continuously-operated gamma-rate recorders (Eberline RM-11) is located around the Test Range Complex at the locations shown in Figure 14. These instruments measure radiation

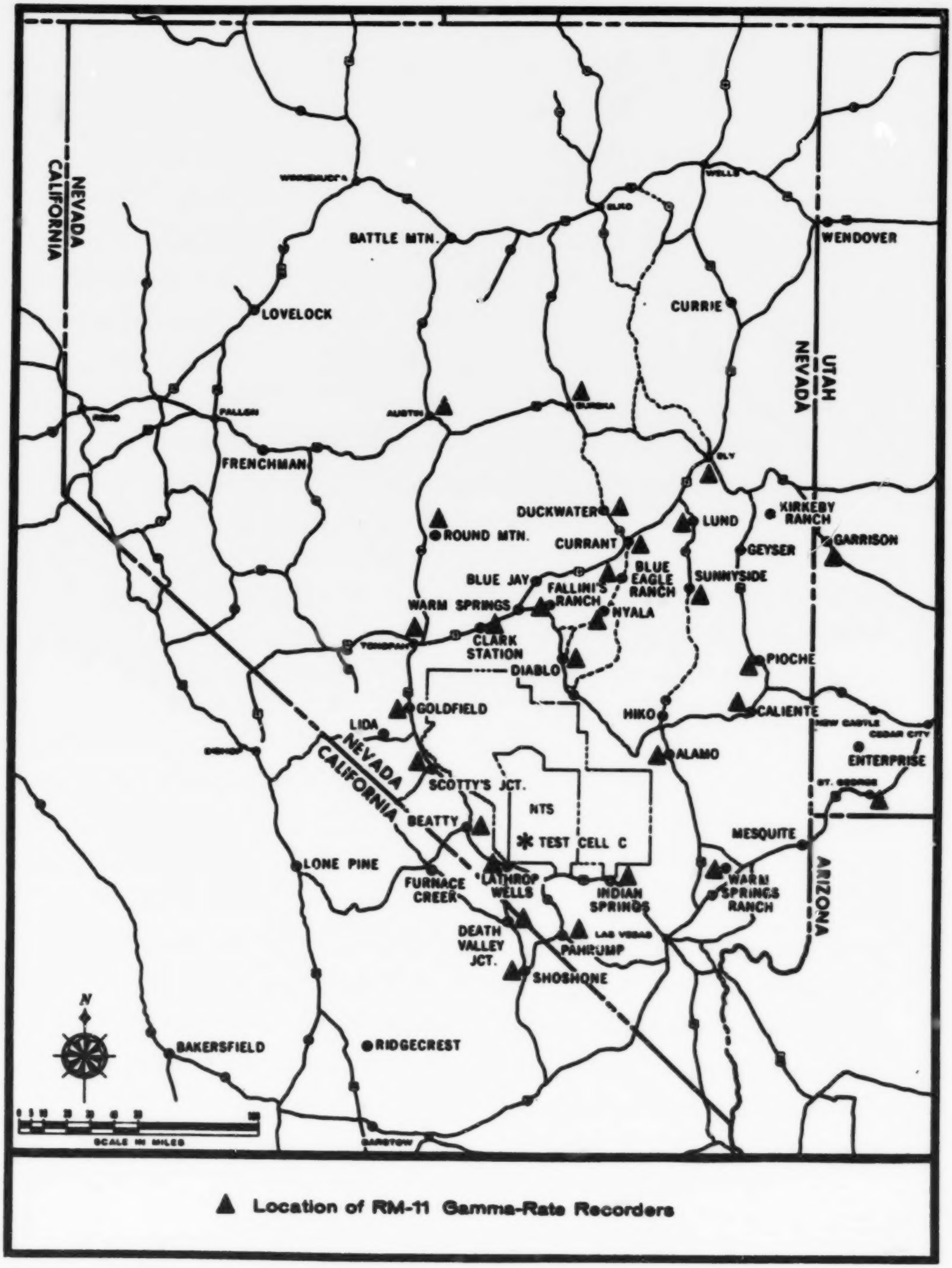

Figure 14. Locations of RM-11 gamma-rate recorders

exposure rates over a range of 0.01 to 100 mR/hr with a Geiger-Mueller detector and record the levels on a 30-hour strip chart. The instrument is accurate to ± 20%, as calibrated with a ^{137}Cs source.

Portable gamma-rate recorders carried by monitors utilize the same 0-2000 mR/hr Geiger-Mueller survey instrument mentioned above coupled to a battery-powered strip-chart recorder. These recorders are used to supplement the routine network of gamma-rate recorders and the radiation readings taken by monitors. The enclosure for each recorder also contains two thermoluminescent dosimeters of the type described in the following section.

Dosimeters

A routine dosimetry network of film badges and thermoluminescent dosimeters (TLD's) is operated continuously. This network, shown in Figure 15, consists of 106 permanent stations with five badges each at 93 different locations. Additionally, about 140 off-site residents are provided with one badge each. DuPont Type 545 film is used, which is calibrated with a ^{137}Cs source. The film has a lower limit of detection of 30 mR with a reading accuracy of ± 50% from 30 to 100 mR and ± 10% from 100 to 2000 mR for gamma radiation above 50 keV. In addition, 88 of the fixed stations are each equipped with three EG&G Model TL-12 TLD's. The lower limit of detection for the TLD's is 1 mR or 15% of the established background (determined over a time period equivalent to TLD exposure time), whichever is greater. The upper limit is 5000 R. The TLD system (TLD and reader) is calibrated with a ^{137}Cs source and has an overall accuracy of ± 10%.

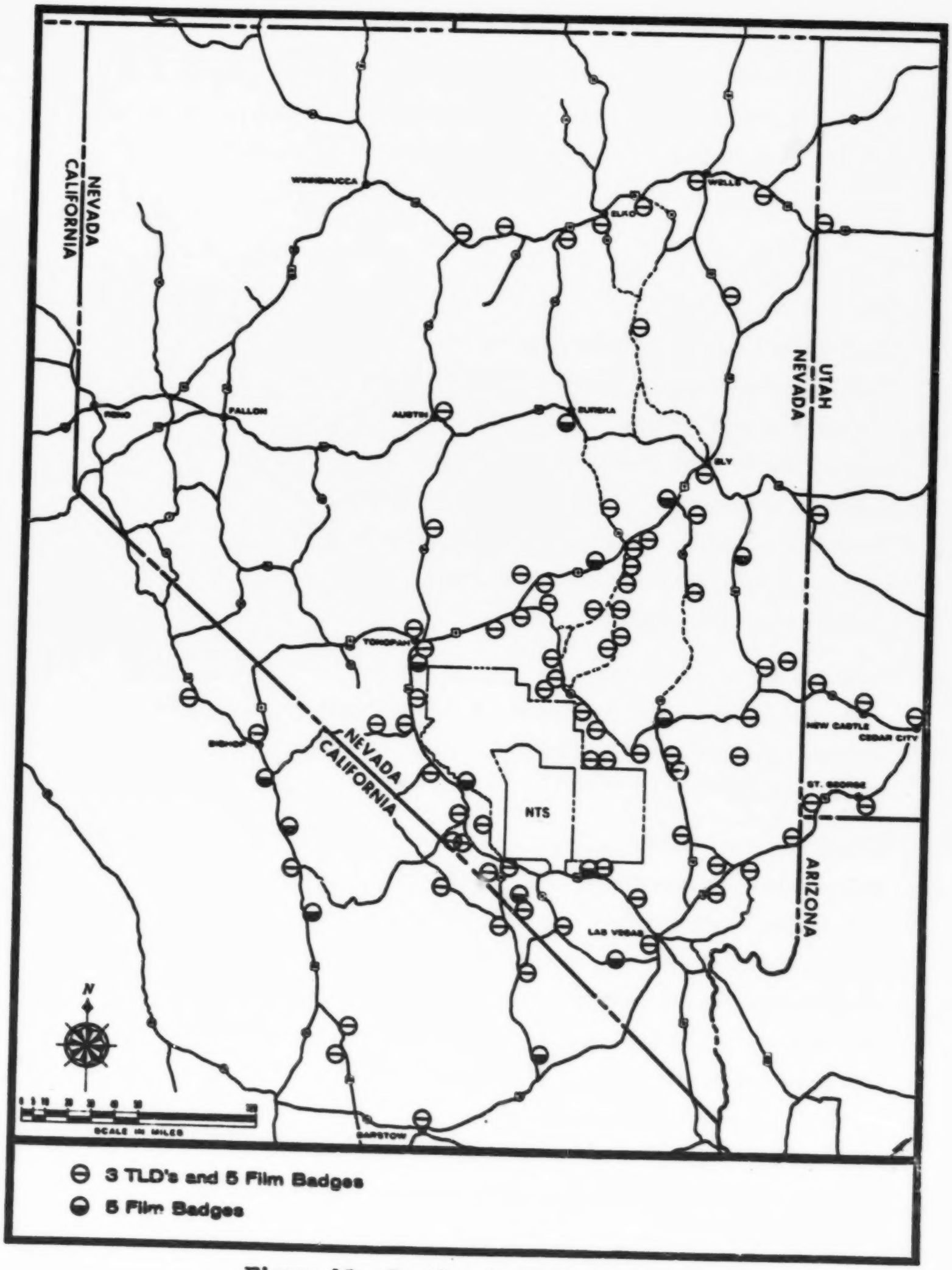

Figure 15. Routine dosimetry network

Following nuclear tests which release airborne radioactivity, additional TLD's are placed at intervals along highways crossing the effluent trajectory and at populated locations to supplement the monitoring coverage of the routine dosimetry network.

Air Samples

The routine network of 103 permanent air samplers of the Air Surveillance Network (ASN) (Figure 16) is used for measuring concentrations of airborne radioactivity on a daily basis. These stations, sampling at about 9 cfm, collect airborne particles on 4-inch diameter glass-fiber filters. Twenty-two of the stations next to the Test Range Complex each operate routinely with a 4-inch diameter charcoal cartridge following a particulate filter. By telephone request, charcoal cartridges can be placed in additional stations and the standby stations can be activated.

Portable air samplers carried by field monitors supplement the ASN stations to cover cloud passage. These samplers also use 4-inch diameter glass-fiber filters and charcoal cartridges and operate at about 12 cfm.

All filters are counted for gross beta radioactivity on a low background, thin-window, proportional counter. Results are reported in pCi/m^3 and $\mu Ci \cdot sec/m^3$ extrapolated to end of collection time. Those filters containing reactor-related radioactivity and all charcoal cartridges are analyzed by gamma spectrometry with a 4- by 4-inch NaI crystal and multichannel analyzer. The concentrations of individual radioisotopes are reported in pCi/m^3 and $\mu Ci \cdot sec/m^3$ extrapolated to end of collection. For both gross beta and radioiodine radioactivity collected from 300 m^3 of air, the Minimum Detectable Activity (MDA) is 0.1 pCi/m^3 for counting times of 2 minutes and 10 minutes, respectively.

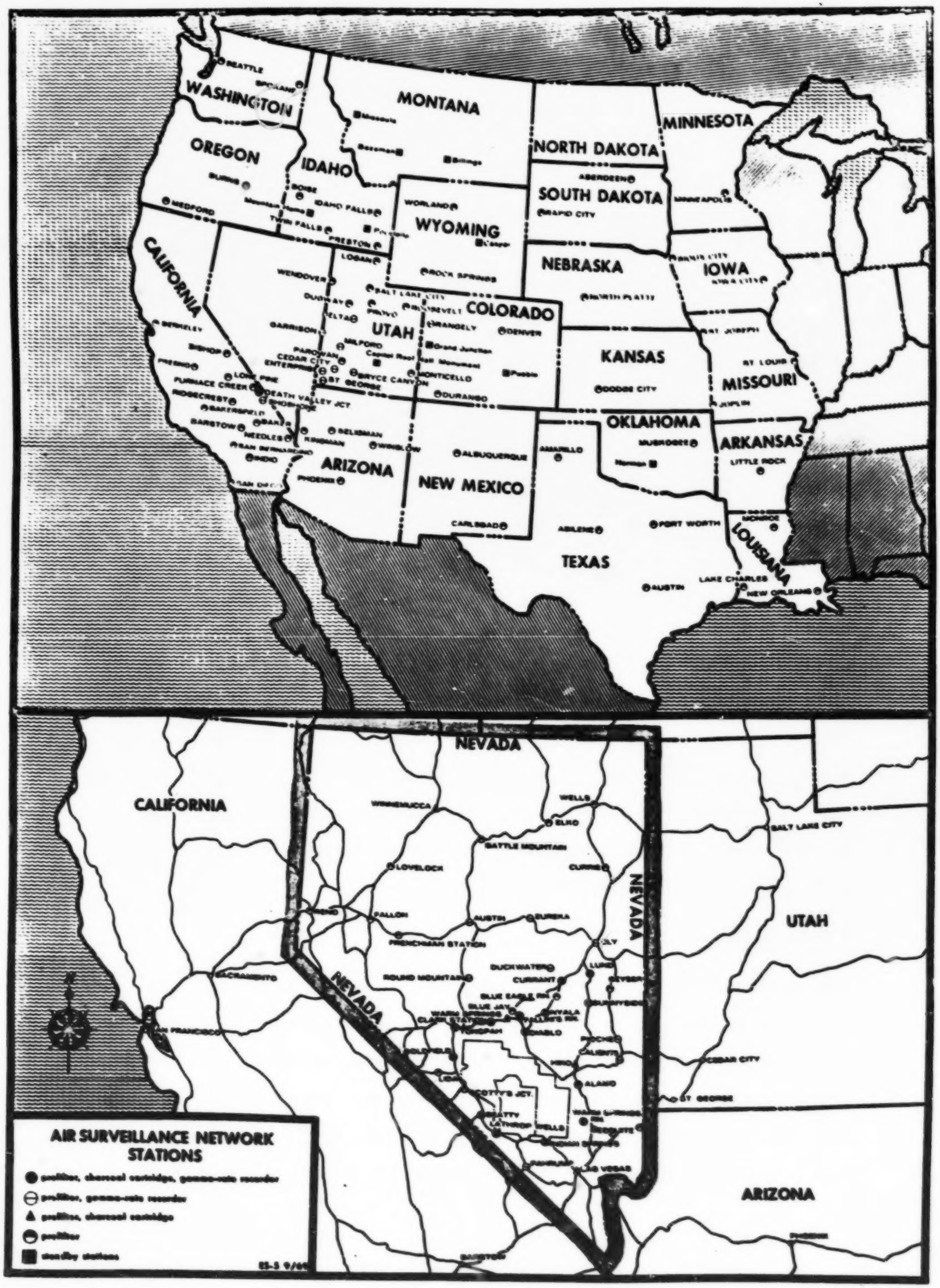

Figure 16. Air surveillance network

Vegetation Samples

Following cloud passage, samples of natural vegetation are collected along highways and at populated locations to augment or substantiate other evidence of the radioactive deposition pattern. Samples are counted for gross gamma radioactivity and qualitatively analyzed by gamma spectrometry to determine whether samples are positive or negative for test-related radioactivity.

Samples of cow feed are collected at all locations where milk samples are collected and analyzed by gamma spectrometry. The concentrations of individual radionuclides identified in the samples are reported in pCi/kg if greater than the MDA of 50 pCi/kg for a 10-minute count and sample weight of 1 kg.

Milk Samples

One-gallon milk samples are collected from dairy farms and family milk cows located within the cloud path. Samples of 3.5 liters are analyzed by gamma spectrometry techniques. The lower limit of detection for ^{131}I and ^{133}I is about 20 pCi/l for a 20-minute counting time. Samples containing test-related radioactivity are also analyzed by radiochemistry techniques for ^{89}Sr and ^{90}Sr, which have MDA's of 5 pCi/l and 2 pCi/l, respectively.

Water Samples

One-gallon water samples are collected within the effluent trajectory from stock tanks at locations where milk samples are collected and from potable water sources. All samples are analyzed by gamma spectrometry. Those samples containing test-related radioactivity are also analyzed by radiochemistry methods for ^{89}Sr and ^{90}Sr. The minimum detectable concentrations are the same as those for milk.

APPENDIX B

CALCULATIONS OF THYROID DOSE

The dose rate to the thyroid may be described by the equation

$$dD/dt = K\,E\,\dot{A}\,\exp -(\lambda_{eff}t)$$ where:

dD/dt = dose rate per unit time

K = dimensional constant

E = effective energy of beta and gamma radiation, MeV per disintegration

A = concentration of radioiodine in thyroid, μCi/gm

λ_{eff} = effective decay constant, 1/unit time

t = time after deposition in thyroid

This assumes that the radioiodine is uniformly distributed throughout the thyroid and that the size of the thyroid is large compared to the range of the beta particles.

The total dose is estimated by integrating the above equation from time zero to infinity assuming D = O at time zero.

$$D = KEA\int_o^\infty \exp -(\lambda_{eff}t)\,dt$$

$$D = (-1/\lambda_{eff})\,KEA\,\exp -(\lambda_{eff}t)\,\Big|_o^\infty$$

$$D = O + KEA/\lambda_{eff}$$

Dose from Inhalation of Radioiodines

The actual values for the parameters in the dose equation for ^{131}I are as follows:

$$K = \frac{1\text{ rad}}{100\text{ erg/gm}} \times \frac{\text{erg}}{6.24\times10^5\text{ MeV}} \times \frac{3.7\times10^4\text{ dis}}{\mu\text{Ci}\cdot\text{sec}} \times \frac{8.64\times10^4\text{ sec}}{\text{day}}$$

$$K = \frac{51.2 \text{ rad} \cdot \text{gm} \cdot \text{dis}}{\text{MeV} \cdot \mu\text{Ci} \cdot \text{day}}$$

$$E = 0.23 \text{ MeV}^{(11)}$$

$A = \frac{\chi B f}{m}$, where:

χ = time-integrated concentration of radioactivity, $\mu\text{Ci} \cdot \text{sec}/\text{m}^3$

B = breathing rate of standard man, $2.32 \times 10^{-4} \text{ m}^3/\text{sec}$ [11] (averaged over 24 hours)

f = fraction of inhaled radioiodine reaching the thyroid, 0.23 [11]

m = thyroid weight of standard man, 20 gm

$$A = \frac{(2.32 \times 10^{-4} \text{ m}^3/\text{sec})(0.23)\chi}{20 \text{ gm}}$$

$$\lambda_{eff} = 0.693/(\text{effective half-life for } {}^{131}\text{I})$$

$$\lambda_{eff} = (0.693)/7.6 \text{ days}^{(11)}$$

Substituting these parameters, the dose equation becomes:

$$D = \frac{(51.2)(0.23)(2.32 \times 10^{-4})(0.23)(7.6)\chi}{(20)(0.693)}$$

$$D(\text{rads}) = (3.45 \times 10^{-4} \frac{\text{rads} \cdot \text{m}^3}{\mu\text{Ci} \cdot \text{sec}}) \chi \left(\frac{\mu\text{Ci} \cdot \text{sec}}{\text{m}^3}\right)$$

$$\text{or,} \quad D(\text{mrad}) = (0.35 \frac{\text{mrad} \cdot \text{m}^3}{\mu\text{Ci} \cdot \text{sec}}) \chi \left(\frac{\mu\text{Ci} \cdot \text{sec}}{\text{m}^3}\right)$$

For the dose to a child's thyroid the above equation must be multiplied by a factor of 3 to account for differences in thyroid weight and breathing rates (m^3/day) between an adult and a child
(3 = 20 gm/2 gm x 6 m^3/20 m^3).

For other radioiodines the dose equation changes according to differences in effective half-life and effective decay energies. The dose equations for ^{133}I and ^{135}I are as follows:

$$^{133}I,\ D(mrad) = \frac{(0.093\ mrad \cdot m^3)}{(\mu Ci \cdot sec)} X$$

$$^{135}I,\ D(mrad) = \frac{(0.029\ mrad \cdot m^3)}{(\mu Ci \cdot sec)} X$$

In addition to differences in effective half-life and effective beta particle energies, the dose equation for ^{132}I is affected by the rapid decay of ^{132}I in the blood stream before it gets to the thyroid and by the decay rate of ^{132}Te, the precursor of ^{132}I (9, 10). With these effects incorporated the dose equation for ^{132}I becomes

$$D(mrad) = (5.1 \times 10^{-2}\ mrad \cdot m^3/\mu Ci \cdot sec) X$$

where X is the time-integrated concentration of ^{132}Te.

Dose from Ingestion of Radioiodines

For ingestion, parameter A, integrated concentration of radioiodine in the thyroid, is defined by $A = \frac{CVf}{m}$ where,

C = the time-integrated concentration of radioiodine in milk, pCi·day/l (time-integrated concentration from time zero to infinity assuming that the effective half-lives of ^{131}I, ^{133}I, and ^{135}I in milk are 5 days, 21 hours, and 6.7 hours, respectively)

V = the rate by which milk is consumed by a child one year old or less, 1 liter/day [12]

f = fraction of ingested radioiodine reaching the thyroid, 0.3 [11]

m = thyroid weight of a child one year old or less, 2 g [12]

With the values for V, f, and m substituted,

$$A = \frac{(1 \text{ liter/day})\ (0.3)}{2 \text{ g}}\ C, \text{ or}$$

$$A = \frac{0.15 \text{ liter}}{\text{day} \cdot \text{g}}\ C$$

For ^{131}I the dose equation $D = KEA/\lambda_{eff}$ becomes applicable to milk ingestion with the above expression for A substituted.

$$D\ (\text{mrad}) = (5.12 \times 10^{-2}\ \frac{\text{mrad} \cdot \text{g} \cdot \text{dis}}{\text{MeV} \cdot \text{pCi} \cdot \text{day}})\ (0.23\ \frac{\text{MeV}}{\text{dis}})\ (\frac{0.15\ \text{l}}{\text{day} \cdot \text{g}})\ (\frac{7.6 \text{ day}}{0.693})\ C$$

$$\text{or, } D = \frac{(1.94 \times 10^{-2} \text{ mrad} \cdot \text{l})}{(\text{pCi} \cdot \text{day})}\ C\ \frac{(\text{pCi} \cdot \text{day})}{\text{liter}}$$

For other radioiodines, the above dose equation changes according to differences in effective half-life and effective decay energies to become:

$D = (5.22 \times 10^{-3})\ C$ for ^{133}I and

$D = (1.62 \times 10^{-3})\ C$ for ^{135}I.

APPENDIX C.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP IV

(Concentrations Extrapolated to End of Collection Period)

Location	Time On / Off	Date On / Off June 1968	Sampling Period (hours)*	Coll. Medium	Gross Beta (pCi/m^3) / ($\mu Ci \cdot sec/m^3$)	Isotopic Results (pCi/m^3) / ($\mu Ci \cdot sec/m^3$) ^{131}I	^{132}Te	^{133}I
Hwy 25, 11.5 mi W of Hancock Summit, Nevada	1715	26	16.7	PF	370	20	73	97
	1000	27			22	1.2	4.4	5.8
				CC	--	6.0	ND	49
					--	0.36	ND	2.9
43° 62 mi								
Hiko, Nevada	1650	26	19.2	PF	250	12	41	56
Coal Valley	1200	27			17	0.83	2.8	3.9
33° 93 mi				CC	--	3.6	ND	21
					--	0.25	ND	1.4
Hiko, Nevada	0730	26	24.0*	PF	45	1.6	6.2	8.2
47° 78 mi	0730	27			3.8	0.14	0.54	0.71
				CC	--	0.8	ND	5.6
					--	0.07	ND	0.48
	0730	27	24.0*	PF	3.3	0.1	0.7	ND
	0730	28			0.29	0.009	0.06	ND
				CC	--	ND	ND	ND
					--	ND	ND	ND
Alamo, Nevada	0850	26	23.5	PF	29	0.9	4.0	4.8
59° 72 mi	0720	27			2.5	0.08	0.34	0.41
				CC	--	0.4	ND	1.9
					--	0.03	ND	0.16
	0720	27	23.8	PF	2.6	0.2	0.6	ND
	0710	28			0.22	0.02	0.05	ND
				CC	--	ND	ND	ND
					--	ND	ND	ND

APPENDIX C.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP IV

(Concentrations Extrapolated to End of Collection Period) (continued)

Location Azimuth Distance	Time On Off	Date On Off June 1968	Sampling Period (hours)*	Coll. Medium	Gross Beta (pCi/m^3) / ($\mu Ci \cdot sec/m^3$)	Isotopic Results (pCi/m^3) / ($\mu Ci \cdot sec/m^3$) ^{131}I	^{132}Te	^{133}I
Fallini's Twin Springs Ranch	0430	26	25.3	PF	3.4	ND	ND	ND
	0530	27			0.31	ND	ND	ND
3° 95 mi				CC	--	0.5	ND	ND
					--	0.05	ND	ND
Indian Springs, Nevada	0900	26	24.0	PF	9.3	0.4	1.0	ND
	0900	27			0.80	0.04	0.09	ND
117° 38 mi				CC	--	ND	ND	ND
					--	ND	ND	ND
Bryce Canyon, Utah	0905	27	24.1	PF	8.2	0.40	1.4	ND
	0920	28			0.71	0.035	0.12	ND
76° 233 mi				CC	--	**	**	**
					--	**	**	**
Bishop, California	1700	27	24.0	PF	6.9	0.3	1.6	ND
288° 122 mi	1700	28			0.60	0.08	0.14	ND
				CC	--	**	**	**
					--	**	**	**
Geyser Maintenance Station, Nevada	1533	26	27.6	PF	3.8	0.2	0.7	ND
	1820	27			0.38	0.02	0.07	ND
36° 154 mi				CC	--	**	**	**
					--	**	**	**

APPENDIX C.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP IV

(Concentrations Extrapolated to End of Collection Period) (continued)

Location Azimuth Distance	Time On Off	Date On Off June 1968	Sampling Period (hours)*	Coll. Medium	Gross Beta (pCi/m^3) ($\mu Ci \cdot sec/m^3$)	Isotopic Results (pCi/m^3) ($\mu Ci \cdot sec/m^3$) ^{131}I	^{132}Te	^{133}I
Parowan, Utah	1000	27	24.0	PF	3.4	0.2	0.8	ND
	1000	28			0.29	0.02	0.07	ND
				CC	--	**	**	**
70° 202 mi					--	**	**	**
Monticello, Utah	0800	27	22.5	PF	5.0	0.2	0.7	ND
	0630	28			0.40	0.02	0.06	ND
				CC	--	**	**	**
79° 388					--	**	**	**
Milford, Utah	1200	27	24.0	PF	6.0	0.1	0.5	ND
	1200	28			0.52	0.009	0.04	ND
				CC	--	**	**	**
59° 209 mi					--	**	**	**
Nyala, Nevada	0700	27	24.0	PF	2.0	0.1	0.3	ND
	0700	28			0.17	0.009	0.03	ND
				CC	--	ND	ND	ND
17° 102 mi					--	ND	ND	ND
Capitol Reef National	1703	27	23.9	PF	2.6	0.1	0.5	ND
Monument, Utah	1700	28			0.22	0.009	0.04	ND
				CC	--	**	**	**
70° 293 mi					--	**	**	**

PF - Particulate filter CC - Charcoal cartridge ND - Not detected

* - Sampling periods for permanent ASN Stations are from time meter and not from ON/OFF times recorded by station operators.

** - Charcoal cartridge not used.

NOTE: $\mu Ci \cdot sec/m^3$ is the product of the sampling period and the radioactivity concentration in pCi/m^3. Inhaled radioactivity may be estimated from product of $\mu Ci \cdot sec/m^3$ and individual's breathing rate in m^3/sec.

Air samplers were positive for radioactivity at Butler Ranch, Pahranagat Lake, Tennille Ranch, 32 mi N. Hiko, and 6 mi S. Hwy. Jct. 93/25, however, quantitative data was not obtained.

APPENDIX C.2

MILK AND ASSOCIATED COW FEED RESULTS FOR PHOEBUS 2A EP IV

Location	Date	Milk pCi/l				Cow Feed pCi/kg		Type
		^{131}I	^{133}I	^{89}Sr	^{90}Sr	^{131}I	^{133}I	
Hiko, Nevada	6/27-am	ND	ND	--	--	ND	630	Hay
(Schofield Dairy)	6/27	--	--	--	--	ND	290	Green Chop
49°, 75 mi	6/27	--	--	--	--	120	1000	Hay
	6/28-am	ND	30	<5	<2	100	600	Green Chop
	6/29-am	ND	ND	--	--	250	750	Hay
	6/30-am	30	ND	<5	5	100	ND	Hay
	7/01-pm	30	ND	--	--	ND	ND	Green Chop
	7/02-am	30	ND	--	--	50	ND	Green Chop
	7/06-pm	30	ND	--	--	--	--	--
	7/08-am	30	ND	--	--	--	--	--
	7/09	--	--	--	--	ND	ND	Green Chop
	7/10	--	--	--	--	ND	ND	Green Chop
Alamo, Nevada	6/27	--	--	--	--	ND	240	Hay
(Buckhorn Ranch)								
60°, 70 mi								
Alamo, Nevada	6/27	--	--	--	--	ND	ND	Hay
(Stewart's Dairy)	6/27-pm	ND	ND	--	--	ND	830	Pasture
58°, 72 mi	6/28-am	ND	ND	--	--	ND	ND	Hay
	6/29-pm	ND	ND	--	--	ND	ND	Hay & Green Chop
	6/30-am	ND	ND	--	--	ND	ND	Hay & Green Chop
	7/01-pm	ND	ND	--	--	ND	ND	Hay
	7/01	--	--	--	--	ND	ND	Green Chop
	7/02-am	ND	ND	--	--	ND	ND	Hay & Green Chop
Caliente, Nevada	6/27-am	ND	ND	--	--	ND	ND	Pasture
(Tennille Ranch)	6/28-am	ND	30	--	--	ND	ND	Pasture
62°, 105 mi	6/29-am	ND	ND	--	--	ND	ND	Pasture
	6/30-am	ND	ND	--	--	ND	ND	Pasture
	7/01-am	ND	ND	--	--	ND	ND	Pasture
	7/02-am	ND	ND	--	--	ND	ND	Pasture
Panaca, Nevada	6/27-am	ND	ND	--	--	ND	ND	Hay
(Cox Ranch)	6/28-am	ND	30	<5	<2	ND	ND	Hay
57°, 118 mi	6/29-am	ND	ND	--	--	ND	ND	Hay
	6/30-am	ND	ND	--	--	ND	ND	Hay

ND - Not detected

APPENDIX D.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP V

(Concentrations Extrapolated to End of Collection Period)

Location Azimuth Distance	Time On Off	Date On Off June 1968	Sampling Period (hours)*	Coll. Medium	Gross Beta (pCi/m³) (μCi·sec/m³)	Isotopic Results (pCi/m³) (μCi·sec/m³) ^{131}I	^{132}Te	^{133}I	^{135}I
Queen City Summit,	2014	18	14.6	PF	420	14	65	90	54
Nevada	1050	19			22	0.74	3.4	4.7	2.8
16° 66 mi				CC	--	26	ND	220	31
					--	1.4	ND	12	1.6
Coyote Summit,	1940	18	14.6	PF	480	19	74	110	70
Nevada	1015	19			25	1.0	3.9	5.8	3.7
6.8 mi W on Hwy 25				CC	--	2.9	ND	26	5.3
28° 64 mi					--	0.15	ND	1.4	0.28
Diablo, Nevada	0645	18	24.0	PF	62	2.1	8.7	14	12
8° 74 mi	0645	19			5.2	0.18	0.75	1.2	1.0
				CC	--	0.8	ND	5.6	ND
					--	0.07	ND	0.48	ND
Nyala, Nevada	0700	18	24.0	PF	130	5.0	18	31	28
17° 102 mi	0700	19			11	0.43	1.6	2.7	2.4
				CC	--	1.3	0.6	10	2.7
					--	0.11	0.05	0.86	0.23
	0700	19		PF	4.8	0.2	1.4	0.3	ND
	0700	20			0.41	0.02	0.12	0.03	ND
				CC	--	0.6	ND	0.8	ND
					--	0.05	ND	0.07	ND
Hiko, Nevada	1905	18	18	PF	410	18	75	100	35
14 mi N, 40 mi W	1305	19			27	1.2	4.9	6.5	2.3
25° 100 mi				CC	--	10	ND	77	12
					--	0.65	ND	5.0	0.78

APPENDIX D.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP V

(Concentrations Extrapolated to End of Collection Period) (continued)

Location	Time On	Date On	Sampling Period	Coll.	Gross Beta (pCi/m³)	Isotopic Results (pCi/m³) / (μCi·sec/m³)			
Azimuth Distance	Off	Off June 1968	(hours)*	Medium	(μCi·sec/m³)	^{131}I	^{132}Te	^{133}I	^{135}I
Hiko, Nevada	1825	18	17.2	PF	500	21	81	110	43
14 mi N, 30 mi W	1136	19			31	1.3	5.0	6.8	2.7
30° 96 mi				CC	--	3.3	ND	29	5.2
					--	0.20	ND	1.8	0.32
Hiko, Nevada	1743	18	16.9	PF	170	6.0	26	36	ND
14 mi N, 18 mi W	1038	19			10	0.37	1.6	2.2	ND
33° 93 mi				CC	--	ND	ND	4.9	ND
					--	ND	ND	0.30	ND
Hiko, Nevada	1750	18	17.7	PF	11	0.2	1.8	1.6	ND
49 mi N on Hwy 38	1130	19			0.7	0.01	0.11	0.10	ND
38° 108 mi				CC	--	ND	ND	0.8	ND
					--	ND	ND	0.05	ND
Currant, Nevada	2000	18	14.5	PF	290	12	46	63	40
Blue Eagle Ranch	1110	19			15	0.63	2.4	3.3	2.1
10° 123 mi				CC	--	5.0	ND	37	7.0
					--	0.26	ND	1.9	0.37
Sunnyside, Nevada	1700	18	21.3	PF	77	3.0	14	17	8.8
32° 130 mi	1402	19			5.9	0.23	1.1	1.3	0.67
				CC	--	2.0	ND	15	2.6
						0.15	ND	1.2	0.20

APPENDIX D.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP V

(Concentrations Extrapolated to End of Collection Period) (continued)

Location	Time On	Date On	Sampling Period	Coll.	Gross Beta (pCi/m³)	Isotopic Results (pCi/m³) / (μCi·sec/m³)			
Azimuth Distance	Off	Off June 1968	(hours)*	Medium	(μCi·sec/m³)	^{131}I	^{132}Te	^{133}I	^{135}I
Duckwater, Nevada	2142	18	11.5	PF	99	3.3	15	20	9.8
13° 146 mi	0855	19			4.1	0.14	0.62	0.83	0.41
				CC	--	1.2	ND	6.8	ND
					--	0.05	ND	0.36	ND
	0855	19	24.6	PF	3.2	0.2	0.8	ND	ND
	0800	20			0.28	0.02	0.07	ND	ND
				CC	--	**	**	**	**
					--	**	**	**	**
Currant, Nevada	0620	18	24.0	PF	100	2.5	10	ND	ND
20° 143 mi	0630	19			8.6	0.22	0.86	ND	ND
				CC	--	0.7	ND	ND	ND
					--	0.06	ND	ND	ND
	0630	19	23.5	PF	5.1	0.2	1.6	ND	ND
	0630	20			0.43	0.02	0.14	ND	ND
				CC	--	0.6	ND	ND	ND
					--	0.05	ND	ND	ND
Lund, Nevada	0745	18	24.0	PF	13	0.5	1.8	3.0	ND
26° 157 mi	0745	19			1.1	0.04	0.16	0.26	ND
				CC	--	ND	ND	ND	ND
					--	ND	ND	ND	ND
	0745	19	23.2	PF	15	0.8	4.1	21	ND
	0825	20			1.3	0.07	0.34	1.8	ND
				CC	--	1.2	ND	3.4	ND
					--	0.10	ND	0.28	ND

APPENDIX D.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP V

(Concentrations Extrapolated to End of Collection Period) (continued)

Location	Time On	Date On	Sampling Period	Coll.	Gross Beta (pCi/m³)	Isotopic Results (pCi/m³) / (μCi·sec/m³)			
Azimuth Distance	Off	Off June 1968	(hours)*	Medium	(μCi·sec/m³)	^{131}I	^{132}Te	^{133}I	^{135}I
Geyser Maintenance	1840	18	21.8	PF	29	1.1	4.3	5.1	ND
Station, Nevada	1600	19			2.3	0.09	0.34	0.40	ND
36° 154 mi				CC	--	**	**	**	**
					--	**	**	**	**
Ely, Nevada	0810	18	23.7	PF	25	0.9	3.0	5.3	ND
25° 183 mi	0750	19			2.1	0.08	0.26	0.45	ND
					--	**	**	**	**
					--	**	**	**	**
	0750	19	24.8	PF	15	0.7	3.5	ND	ND
	0845	20			1.3	0.06	0.31	ND	ND
				CC	--	**	**	**	**
					--	**	**	**	**
Shoshone, Nevada	2100	18	13.5	PF	35	1.5	5.2	6.6	ND
Kirkeby Ranch	1035	19			1.7	0.07	0.25	0.32	ND
36° 177 mi				CC	--	0.7	ND	4.2	ND
					--	0.03	ND	0.20	ND
Currie, Nevada	0700	19	9.5	PF	30	1.1	5.1	ND	ND
19° 251 mi	1635	19			1.0	0.04	0.17	ND	ND
				CC	--	**	**	**	**
					--	**	**	**	**
Wendover, Utah	0800	19	24.0	PF	4.3	0.2	1.0	ND	ND
24° 294 mi	0800	20			0.37	0.02	0.09	ND	ND
				CC	--	**	**	**	**
					--	**	**	**	**

APPENDIX D.1

AIR SAMPLING RESULTS FOR PHOEBUS 2A EP V

(Concentrations Extrapolated to End of Collection Period (continued)

Location Azimuth Distance	Time On Off	Date On Off June 1968	Sampling Period (hours)*	Coll. Medium	Gross Beta (pCi/m^3) ($\mu Ci \cdot sec/m^3$)	Isotopic Results (pCi/m^3) ($\mu Ci \cdot sec/m^3$) ^{131}I	^{132}Te	^{133}I	^{135}I
Lathrop Wells,	0725	18	23.2	PF	5.7	0.5	ND	4.0	ND
Nevada	0640	19			0.48	0.04	ND	0.33	ND
208° 15 mi				CC	--	5.7	ND	45	ND
					--	0.48	ND	3.8	ND

PF - Particulate filter
CC - Charcoal cartridge
ND - Not detected
* - Sampling periods for permanent ASN Stations are from time meter and not from ON/OFF times recorded by station operators
** - Charcoal cartridge not used
$\mu Ci \cdot sec/m^3$ is the product of sampling period and radioactivity concentration. Inhaled radioactivity may be estimated from product of $\mu Ci \cdot sec/m^3$ and individual's breathing rate in m^3/sec.

APPENDIX D.2

MILK AND ASSOCIATED COW FEED RESULTS FOR PHOEBUS 2A EP V

Location	Date	Milk pCi/l ^{131}I	^{133}I	^{89}Sr	^{90}Sr	Cow Feed pCi/kg ^{131}I	^{133}I	Type
Cherry Creek,	7/21-am	20	40	<5	<2	ND	ND	Pasture
Nevada	7/22-am	20	ND	<5	4	ND	ND	Pasture
(Paris & Son Ranch)	7/23-am	ND	ND	--	--	--	--	--
17°m 238 mi	7/24-am	30	ND	--	--	ND	ND	Pasture
	7/26-am	ND	ND	--	--	ND	ND	Pasture
Currant, Nevada	7/19-am	ND	ND	--	--	--	--	--
(Blue Eagle Ranch)	7/19-pm	50	280	5	<2	340	2000	Pasture
180 , 122 mi	7/20-pm	60	60	<5	2	180	360	Pasture
	7/21-pm	50	ND	<5	4	150	250	Pasture
	7/22-pm	ND	ND	--	--	110	65	Pasture
	7/23-pm	50	ND	--	--	ND	ND	Hay
	7/24-pm	30	ND	--	--	ND	ND	Hay
	7/25-pm	20	ND	<5	2	ND	ND	Hay & Pasture
	7/31-pm	20	ND	<5	<2	--	--	--
	8/01	--	--	--	--	ND	ND	Hay
Duckwater, Nevada	7/19-am	ND	ND	--	--	--	1500	Pasture
(Halstead Ranch)	7/20-am	90	60	<5	<2	ND	ND	Pasture
13°, 147 mi	7/21	--	--	--	--	120	310	Pasture
	7/22-am	30	ND	<5	<2	130	390	Pasture
	7/23-am	ND	ND	--	--	ND	ND	Pasture
	7/24-am	30	ND	--	--	ND	ND	Pasture
	7/25-26	ND	ND	--	--	ND	ND	Pasture
Nyala, Nevada	7/19-am	ND	ND	--	--	ND	ND	Hay
(Sharp Ranch)	7/20-am	30	100	<5	<2	130	170	Hay
16°, 102 mi	7/21-am	20	40	<5	3	130	ND	Hay
	7/22-am	20	ND	<5	<2	ND	ND	Hay
	7/23-am	30	ND	<5	4	ND	ND	Hay
	7/24-am	ND	ND	--	--	ND	ND	Hay
	7/25-am	ND	ND	--	--	ND	ND	Hay

ND - Not detected

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